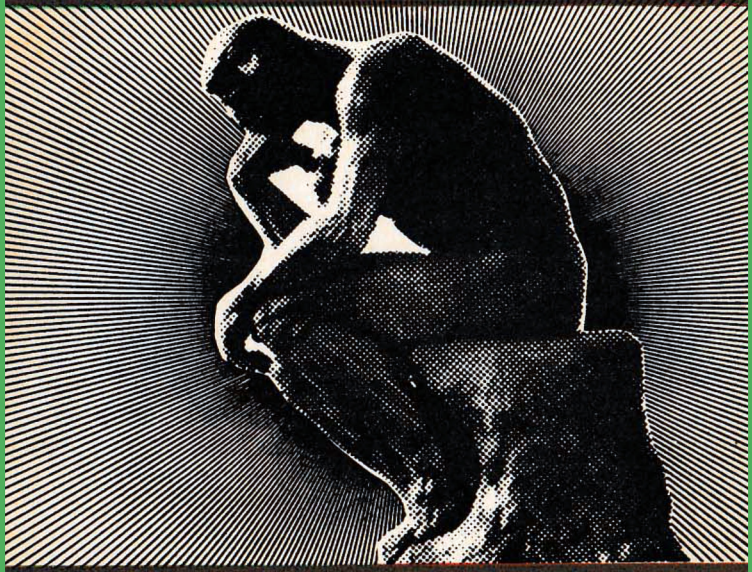
GROUNDS FOR OPTIMISM

Mir Publishers
Moscow



L. BOBROV

Л. Бобров

ФУНДАМЕНТ ОПТИМИЗМА

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Grounds for Optimism

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Up the Down Staircase?

'Icarus, having been taught to fly by his father Daedalus, was destroyed by his rashness. I fear that the same fate may overtake the populations whom modern men of science have taught to fly.' So Bertrand Russell, the English mathematician and philosopher, wrote half a century ago in a debate with the English biologist J.B.S. Haldane.

Their polemic concerned the future of scientific and technical progress and the fate of mankind that is so closely linked with it. It was opened by Haldane in an address that he entitled *Daedalus, or Science and the Future*. For Haldane, Daedalus personified, in himself and in his activity, the future of science and technology and the fate of their creators.

But why Daedalus?

Was it not a strange choice? For it was none other than Daedalus, if we accept the myth, who built the famous Cretan labyrinth, who conceived such cunning pathways that anyone who ventured to enter it could not find his way out again. And in the labyrinth there dwelt the Minotaur, half man, half bull, who devoured human beings.

It might have seemed preferable to take the far more popular figure of Prometheus that inspired Aeschylus to write his immortal tragedy. For hadn't the image of the Titan who stole fire from heaven for the sake of man become traditional in such allegories?

But in fact the choice of Daedalus was not strange. Prometheus and those like him were divine, unearthly creatures, who owed their power and talents, as it were, to their 'rank'. Daedalus, however, was no god, no Titan, but a simple mortal, the captive of Minos, the king of Crete, yet a brilliant engineer and scientist, sculptor and architect, who was in no way inferior in the greatness of his genius to the gods!

His most famous deed made Daedalus the pioneer of bionics and aeronautics, for he fashioned artificial bird's wings so that he and his son Icarus could fly up into the sky and escape from Minos's 'golden cage'.

Bertrand Russell chose another symbol of the future, the fate of Icarus.

The boy's tragedy is well known. Drunk with his feeling of power, he threw precautions to the winds and flew higher and higher toward the sun. Its heat melted the wax that bound the feathers of his wings and they disintegrated and plunged the daring but disobedient boy down into the sea. The heartbroken father turned against his arts and skills and cursed the day and hour when he gave the immature youth, still incapable of sober thought, swift and powerful wings.

Isn't it the same with science? Although inspired by the noblest intentions, does it not open up unprecedented opportunities for a humanity not yet ready for them? Doesn't our whole present civilization risk copying the daring but feckless Icarus, impetuously gaining speed and height in its dizzy flight into the unknown?

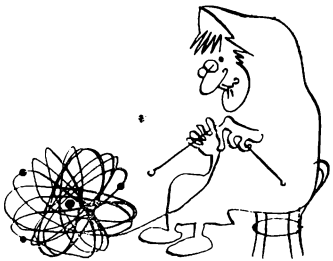
'Whether, in the end, science will prove a blessing or a curse to mankind, is to my mind still a doubtful question,' Bertrand Russell said in his *Icarus, or the Future of Science*. Many Western scientists now share his fears.

His shade continues to prophesy through the mouths of more and more Cassandras. Our descendants, they predict, will face a power famine and a food crisis, and a shortage of raw materials, and lack of a 'place in the sun'.

In 1965 the number of people in the world was estimated at 3250 million (today it is nearer 4000 million). By the year 2000, according to UNO estimates, there will be 6500 million people on earth. Doubled in 35 years! If the present rate of growth continues (at 2 per cent per annum) our descendants will number 15 000 million by the middle of the twenty-first century, and between 35 000 and 40 000 million by the end of it. And so on in the future.

But our planet, like the others, is limited in size. And even if we succeeded in populating the polar regions of the Arctic and Antarctic and covering the oceans with a dense network of artificial islands, the average density of the population by the year 2300 (by then numbering millions of millions) on the 510 million square kilometres of its surface (including water) would be the same as that of present-day cities. The once completely green planet would find itself encased in an armour of asphalt and concrete and transformed into a continuous super-city. And then what?

Man, they would persuade us, will be forced one way or another to imitate Icarus and to aspire to cosmos in search of living space. And not simply for space, but also for power resources and supplies of raw materials. You don't believe it? Then think; the reserves



of ordinary chemical fuels are far from limitless—some countries have scarcely enough of them to last out the next few decades and the richest only enough for several centuries. The atom? In energy content the world's reserves of nuclear fuel are 20 to 30 times those of the ordinary fossil fuels that still remain beneath our feet.

Sooner or later scientists may master the secret of thermonuclear synthesis. Then sea water will become a source of power; but that, too, only seems at first glance to be more than enough. It is impossible, of course, to burn the oceans dry! But the total capacity of thermonuclear power stations could not exceed a certain critical limit, otherwise the land surface and the atmosphere would become overheated and the ice melt (and what good would it be to precipitate another Flood?).

But will man himself survive till then?

After Hiroshima the doleful refrain of the prophecies of other oracles resounded with new force. Was the mastering of the atom 'the greatest triumph of human thought'? A hundred thousand killed and maimed? Whole city blocks obliterated from the face of the earth? And that by the equivalent of only 20 kilotons of TNT? What is to be expected from present-day

thermonuclear bombs that are thousands of times more powerful?

And what are we to say about the progress of medicine, the most human of sciences? Hasn't the victory over disease and early death led to a catastrophic growth of population? And could this 'demographic explosion' not prove more disastrous than a thermonuclear one!?

The average expectation of life has increased, and hopes of superlongevity, and almost of immortality, have appeared for man. But surely that would multiply the number of old people and the non-working part of the population!

Yet every minute someone somewhere in the world still dies of hunger; and in that same minute the number of the world's inhabitants increases by 130 persons (or 70 million a year). And if more than 2000 million people are now systematically undernourished, what will it be like in the year 2000 when the world's population has doubled?

Paul Ehrlich, professor of biology at Stanford University in California, predicts that extensive foci of famine will develop in the Seventies and Eighties and hundreds of millions of people will die of hunger, if thermonuclear bombs or other means of mass destruction have not killed them before that.

In his *Will the Human Race Survive*? the American writer Henry Still cites official warnings that the United States will face a shortage of fresh water in the next 15 or 20 years and shows how industrialization may entail a waterless horror. Industrialization could drive civilization to disaster because it is not simply a weapon in the struggle for existence but also a weapon of mass suicide, a means of exterminating mankind by the last word in science and technology, even without war.



Automation?

'Let us remember', said Norbert Wiener in *The Human Use of Human Beings*, 'that the automatic machine . . . is the precise economic equivalent of slave labour. And labour which competes with slave labour must accept the economic conditions of slave labour. It is perfectly clear that this will produce an unemployment situation in comparison with which . . . even the depression of the Thirties will seem a pleasant joke.'

Much is now expected of thinking machines—creative talent, for instance. The truly fabulous, and at the same time real, possibilities newly created by science and already translated into technology reinforce 'robotphobia' and 'automatonphobia'.

P.E. Cleator, a fellow-countryman of Haldane and Russell, published a book some years ago *The Robot Era* in which he pictured the civilization of 'enforced leisure' that would allegedly be brought about through

'automatization . . . which promises to relieve mankind of much mental effort, particularly of a routine kind'. Before us he conjured up a world of bored spongers 'leading a subsidized existence in metropolis and kraals', 'left to their own unimaginative devices', delivered even from the need to think, turned into lookers-on of machines, debauched by beautiful idleness, doomed to degeneracy, degraded into chronic invalids.

At the beginning of the Sixties, Prof. von Horner in West Germany measured the technical development of civilization as precisely as possible and calculated its span at something around 6500 years—on average. If that were the average it might turn out to be shorter (though that, of course, is less probable).

For Horner rational beings entering on the 'technological age' are threatened by an all too real danger, above all by war or some other (perhaps cosmic) catastrophe, capable of completely annihilating all life on our planet, which could happen within two centuries or so. It might only annihilate highly organized life, which is much more probable, and sooner in time (not in 200 years but in fifty).

But if we manage after all to escape mass death, what then? Even then, says von Horner, there are no grounds for optimism. Physical or mental degeneracy and extinction are not excluded (probably within thirty millenia). An interest in science and technology may be lost even earlier (in 10 000 years), which once again would entail disastrous consequences.

One way or the other, in short, the outlook is bad. Concern with scientific and technical progress, or loss of it, leads to 'the end of the world'. The road to nowhere.

The world of the future is a real hell and we should escape from it wherever we see a way out. But where?

'Back!' Prof. Freeman Dyson of the Princeton Institute of Advanced Studies summons us in the *Bulletin*

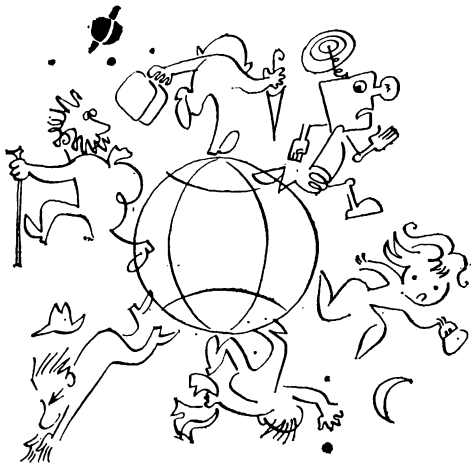
of the Atomic Scientists. Back ... to space, to cosmos!

'We cannot (of course) go back to the Middle Ages or to classical Greece, even if we wished to,' he regrets, and then expounds his own idea of 'progress backwards'.

When we list the most fruitful periods of human history, he says, we invariably recall fifth-century Athens and fourteenth-century Florence. And is it not true that both those cities, or rather city-states, were not much bigger in size or population than a twentieth-century village? Their populations were small—but 'what an astonishing concentration of achievement' they produced 'within a hundred years'. And in each case 'the outburst of genius', for some reason, followed a period, a quite long period, when the old city had existed 'rather isolated from its neighbours and quarrelling with them incessantly'.

It seems plausible to him that 'we are historically attuned to living in small exclusive groups'. Unfortunately, against 'cultural isolation' and constructive 'clannish exclusiveness' stand 'the three great forces of technology' demanding the uniting of humanity: the arms race ('the forces of weaponry'), population growth, and pollution. But do not despair, Dyson comforts us; there is a way out. 'I foresee that the ultimate benefit of space travel to man will be to make it possible for him once again to live as he lived through prehistoric time'.

The colonizing of asteroids by isolated small groups would convert them into flourishing oases of civilization where the creative life of pioneers would be in full vigour. (Dyson says nothing of how the hermits would manage without close contact with neighbours and broad exchange of information; but that, probably, is how they would breed discoverers of already discovered Americas and inventors of already invented bicycles.)



There is another argument in favour of cosmic Robinson Crusoes: the human race would become indestructible and immortal if some of its members could emigrate to lands beyond the skies and find refuge on uninhabited islands in the solar system. Ninety-nine per cent of mankind could perish in a nuclear catastrophe, Dyson estimates, but the refugees in space would survive, and some of them, possibly, would return to Earth in order to re-colonize it.

So mankind, in striving for the peaks, the grave diggers of history assure us, would sink to the depths.

The American social scientist Bernard Barber, who claims that 'science has become for many of us a "social problem" like poverty and juvenile delinquency, says men want to "do something about it".' As for poverty and crime, the problem is clear; we must fight them. But science? 'We shall do nothing well, of course, unless we really understand science and the nature of its social consequences.'



Admiral Hymen Rickover, a fellow-countryman of Barber's who also resorts to philosophy, has called on lawyers to defend the world against the disorder and violence of science and technology, the potential of which to harm man and society has become incredible.

Rejecting 'bogus pride about the "unquenchable human spirit"' as a refuge (in an article in the American weekly *Nation* entitled 'Abyss of Progress'), E.J. Mishan, a reader in economics at the London School of Economics, seems to think that investigatory thinking (or 'empirical research') is an obstreperous mount that needs curbing, and that humanity may be 'predestined to soar onward "with compulsion and laborious flight" to a doom of its own making.'

'In a dispensation wiser than any we can readily visualize,' he wrote, 'one in which it was finally recognized that no matter how "exciting" or "efficient" was an innovation, its ultimate contribution to human happiness was likely to be slight, whereas the risk of its causing social disharmony or ecological disaster was large—we could, for a while, permit scientists to go on probing the universe if they wished, provided

we took measures to ensure that they did not change it.'

Half a century ago, when Haldane read his *Daedalus* paper in Cambridge, he said: 'The possibility has been suggested that the progress of science may cease through lack of new problems for investigation.' Today people talk rather differently—about the growing excess of problems, and of how science, drowning in a sea of problems, is entering a period of saturation, a time of senile decrepitude and lowered productivity; about its 'ceiling' being not far distant, and science reaching it in a few decades, i.e. within the span of one generation. And its products are already so costly, it must be said, that they do not always find a market—the human brain simply cannot cope with the avalanche, the veritable typhoon of scientific publications.

The words 'scientific and technical progress' used to instil confidence in people that sooner or later every problem facing humanity would be solved; but now there are people who are robbing society of that consolation. The French sociologist Raymond Aron, for example, automatically excludes the idea of progress.

Those who deny progress assure us that it is allegedly impossible to find criteria for it. In their view humanity is running round in circles in an involved labyrinth of history, mistaking old paths for new ones, without a clear perspective, and not knowing where it is going or why. Or rather, a quite definite 'perspective' awaits it—death through meeting a reincarnated Minotaur.

Is such a frame of mind really possible in our day, in the age of the scientific and technical revolution? It seems that it is quite possible. Furthermore, it is not rare, and is nothing new. But is it justified?

In Paul Lafargue's *The Economic Determinism of*

Karl Marx there is a remarkable passage that tears a hole in the smokescreen of bourgeois sociology about humanity's road to the future as Marx saw it. 'The idea of Progress and of evolution had an extraordinary vogue in the first years of the nineteenth century, when the Bourgeoisie was still drunk with its political victory and the prodigious development of its economic wealth.... The entry of the Proletariat on the political scene in England and in France gave rise to disquiet in the mind of the Bourgeoisie about the eternal continuance of its social dominance; gradual Progress lost its charms.'

Is that not why people try importunately to persuade us that humanity 'has lost its way' in the labyrinth of history? That scientific and technical progress, development from the lower to the higher, is an illusion? That there is no forward movement? That time, as it were, has stood still?

On the cover of the American *Bulletin of the Atomic Scientists* there is a clockface with the hands approaching twelve. In a little while, they imply, it will strike midnight. The journal—the organ and mouthpiece of scientists who would warn the world of the nuclear catastrophe threatening it—would remind us that we are on the threshold of the final hour. The gloom of a night that may prove eternal is nigh.

But why this gloom? Is the twelfth hour necessarily midnight? Why not noon? Sunny midday, the heat of work, after which come rest and the evening of another working day.

The hands of the clock on the *Bulletin's* cover are frozen into immobility, as if they do not want to approach twelve o'clock. Time, as it were, has stood still.

But has it stood still?

Forward, O Time!

It happened not long ago. But it was long ago.

On 20 December 7208 a remarkable event occurred. Time seemed to jump back five and a half millenia.

On that day crowds of Moscovites had gathered as usual around the traders' stalls on Red Square outside the Kremlin. Suddenly, above the hubbub of the market-place, there sounded the regular beating of drums, and the crowd, hearing that familiar 'call sign', rushed toward the Kremlin.

Raising his voice as loud as he could, the crier read out the latest edict of the Czar's. It was enjoined that henceforth and forever more years would be reckoned not 'from the Creation' but from 'the birth of Christ', and would begin not on the first of September as before but on the first of January. So 20 December 7208 was suddenly transformed into 20 December 1699.

The reform of the calendar adopted in those days in Russia produced so great an impression that it pushed another, no less important innovation into the background. That same edict also ordained that the clock on the Spassky (Saviour) Tower, on the

face of which there had been only one (hour) hand, would be replaced by one with two hands, for minutes as well as for hours.

That was not long back, less than three centuries ago. And what are 300 years on the scale of history? A moment only.

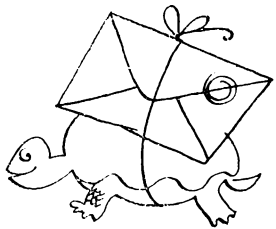
A moment on whatever calendar we use—whether cosmological or geological or anthropological. 'Since the Creation', if by that we mean the origin of the solar system and our planet, gives us a time scale around 5000 to 6000 million years. And 'from the birth of the Son of Man', if we take that to be the appearance of *Homo sapiens*, is about 100 000 years.

To visualize the ratio between these quantities better, as they are not easy to grasp, let us 'compress' the time scale, taking the 5000 million years of old Mother Earth as one year. Then the period when apes evolved into men, approximately 600 000 years ago, becomes a fleeting hour. And the thousand centuries of the road trod by *Homo sapiens* is shortened to a ten minute stroll.

As for the 270-odd years that separate us from Peter the Great's transformation of the old Russian system of chronology, it will indeed appear momentary on our scale, something around a second and a half. A mere trifle compared with eternity!

Surprisingly enough, such comparisons are probably resorted to more readily as a routine 'argument' by those who preach the 'brevity of earthly existence', with all its evolutions and revolutions, scientific progress, and so on and so forth. Attempts to improve the world around us, they say, are 'vanity of vanities; all is vanity'. Rubbish!

It happened long ago, very long ago, on the eve of the eighteenth century. A whole 273 years have passed since then, in other words 100 000 days, or



2 400 000 hours. Astronomical figures. Can you imagine how many working hours, how many man-hours that would make? Millions, tens of millions more! It is a gigantic period if we measure it not by centuries but in terms of the achievements of the mind and hands of humanity.

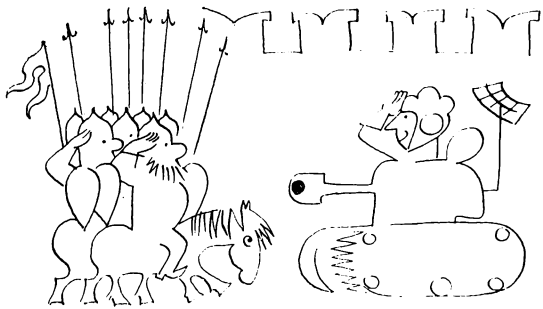
To get an idea of the leaps and bounds that have been made in the past three centuries it is enough to switch on the radio.

When you hear the Moscow, or London, or Delhi time signal, and have listened to the latest news, remember this—in those days news spread to everyone from town to town at the speed of the stagecoach. Distant parts of states like Russia waited months for it.

Today radio waves carry information at the speed of light; we can receive it round the clock, at any time and in any place. Wherever events happen, even in outer space, they become the property of the whole world, and can be followed not merely by listeners but by viewers as well.

Anyone of us, wherever we are, having switched on our television set, can see, without getting out of our favourite armchair, what is going on where it happens, be it on earth or on the moon.

And when Intervision, say, transmits reports from



the launching pads from which whole flotillas of Soyuz spacecraft have been sent into outer space, or from Red Square when the public acclaim spacemen, viewers in other countries, watching with the Soviet television audience, see with their own eyes the enormous changes that have transformed the old Russia of drozhky drivers and post coachmen, bast shoes, and hempen homespun.

Isn't that progress?

And what about the military parades on Red Square on November 7th?

When a Russian sees the familiar outlines of rockets and hears the usual roar and clatter of motors and tracked vehicles, he may recall that here, before these same Kremlin walls, the halberds and muskets of seventeenth century foot soldiers once floated majestically past. And when the 'armoured troop carriers' of those days appeared, there resounded the clatter of hooves and the stamping of dragoons' horses, riders and steeds clad in metal (the mailed horsemen mounted on 'four-footed cuirassiers' were real 'living tanks'). That heavy cavalry was reputed to

be a powerful force and was the pride of every army of the day.

The unhurried rhythm of those times sounded in the drum rolls of the town criers, in the doleful singing, to the accompaniment of harness bells, of the post coachmen, in the leisurely progress of Peter's innovations over the expanses of Russia, and was literally underlined by the quiet measured chimes of the Kremlin clock, on whose dial a single hand moved decorously for the hours.

To some admirers of the patriarchal past, that world may really seem idyllic. Then you had none of the commotion of our vast cities with their endless streams of pedestrians and motor vehicles—no factory smoke, no radio and television daily upsetting one's nerves with vivid impressions, no communiques about the wars raging in various corners of the world or about ever more powerful nuclear, chemical and bacteriological weapons.

Peace and harmony, divine bliss.

But was it so?

Think of old wooden Russia—smoky spills that scarcely dispelled the gloom in the corners of the best ('lighted') room; cattle in the peasants' huts along with people; carts and sledges bumping along unmade roads; wooden ploughs scratching the fields as they had for hundreds of years before; exhausting toil; peasants, men and women and children, living from hand to mouth, labouring from dawn to dusk to gain a wretched subsistence; corvée three days a week on the lord's manor and sometimes all seven days; ruthless dues and exactions, imposed not only for their holdings but on top of that also for the baths, for the ferry, even for beards and oak coffins; life service as a soldier; frequent wars; epidemics.

Strange as it may seem, it is a fact that there are

still people, in our day, who seriously think that some time in the past, long, long ago, a 'golden age' reigned on earth. Here, for example, is an extract from a letter sent to *Izvestia* by a reader in the town of Kirov:

'Take our mothers and fathers, our grandmothers and grandfathers; when they died, they'd lived at least a hundred years, and many to more than a hundred. And now, if someone lives to a hundred, they write about it in the newspapers, as a very rare incident! There was little illness.... I reckon that man's life gets shorter as culture develops. People used to live to 150, were taller, and had stronger constitutions.'

A profound delusion! Echoes of Bible stories about superlongevity (the patriarch Methuselah, for example, is said to have died when he reached the age of 969). Here are some facts and figures that I've taken from the work of Prof. B. Urlanis, an eminent Soviet demographer.

Records for longevity (120 to 150 years of age) were established in the past, of course, but they are much more frequent now. If we take only the average expectation of life, a mass index that makes it possible to estimate the health of a population as a whole, it remained at a very low level, between 20 and 30, everywhere in the world for thousands of years—in antiquity, in the Middle Ages, and later.

In 1761 Mikhail Lomonosov sent a letter to Count Shuvalov 'on the maintenance and multiplication of the people' in which he drew the attention of this influential patron to the high mortality in Russia. 'Things are bad as regards apothecaries' shops', he wrote. Midwifery was at such an antiquated level that in many cases mothers had no surviving children from ten or fifteen births. Lomonosov proposed in-



creasing the number of doctors and apothecaries, and organizing medical education. His letter, however, had no effect.

Epidemics were a real scourge of our forefathers. In such conditions, obviously, people in the mass died in the flower of life and very few lived to advanced old age. Even at the end of the nineteenth century the average expectation of life in Russia had hardly reached 32. After the Soviet Revolution it began to rise with unprecedented rapidity, reaching 44 in 1927, 64 in 1939, and 70 at the beginning of the Sixties.

Is that not the result of progress? Of scientific and technical progress in general, but particularly in the field of medicine?

In the twentieth century we have succeeded in understanding the nature of many illnesses that remained a mystery to our forbears, and to develop effective drugs and new methods of diagnosis and treatment. No small role in that has been played by the advances of physics, chemistry, biology, electronics, and instrument-making.

Yes, an immense role has been played by discoveries and inventions borrowed from the most varied fields of science and technology. But has it only been a matter of that?

A few years ago the South African surgeon Christian Barnard transplanted a human heart for the first time in the world. The sensational operation prolonged the lives of patients doomed, it seemed, to certain and rapid death. But the average expectation of life for the Bantus in South Africa is only 35. And there, and in many other African countries, millions of the aboriginal population die prematurely even when saving them from death is no problem, when a doctor would not have to perform miracles, where it is simply a matter of the availability of very ordinary chemist's shops and clinics.

'For victory over death to become not just a single episode, an isolated sensation, but a truly mass phenomenon, certain achievements in medicine are indispensible,' says Prof. Urlanis. 'That means a well developed health service and system of social insurance that can convert the potentialities of medicine into real achievements, and make them available to each and everyone, and can satisfy the needs of the population for drugs, doctors, hospitals and sanatoria. And if the average expectation of life in the Soviet Union has risen at an unprecedented rate such as no other state has ever known, we owe it above all to social progress.'

The health of Soviet people is looked after by some 700 000 doctors and more than two million nurses and other trained medical personnel. Every fourth doctor in the world is a Soviet citizen, although the population of the USSR is only one fourteenth that of our planet. For every 10 000 inhabitants it has 28 doctors (against two in 1913), while the USA,

West Germany, and many other developed countries have less than twenty (and India only two). The rise in national well-being recorded in the plans of the Soviet state, plus the further advances of medicine itself, will raise the average expectation of life even higher.

These facts, though few, are quite eloquent. And if somebody today suddenly dreams that our present age has all of a sudden changed into a past one, his dream will be a nightmare.

There is no doubt that many events of days long past are worth admiring and even enthusing about. It is possible, for example, to sing, as Pushkin did, of the times when Russia was young and straining its forces in battle, matured with the genius of Peter the Great, 'the glorious skipper'.

One can enthuse, as Freeman Dyson does, about Athens of the days of Pericles (fifth century B.C.), when ancient democracy was in flower. Or about Florence of the fourteenth century, when the Renaissance was beginning. And why not?

The Renaissance was (as Engels put it in the *Dialectics of Nature*) 'the greatest progressive revolution that mankind has so far experienced, a time which called for giants and produced giants—giants in power of thought, passion, and character, in universality and learning'.

One of the giants of the Renaissance and one of its first humanists was the Florentine Giovanni Boccaccio, the author of the *Decameron*, who proclaimed human personality, with all its worldly aspirations, virtues, and sins, the highest value, and declared that simple mortals were worthy of the place mediaeval ideology assigned to God.

But if we judge Florence of the fourteenth century solely by such 'sources' as the spicy stories of Boc-



caccio's characters, we would get a very, very one-sided impression. And isn't that how the idealized pictures of 'Blessed Florence' arose, and of the 'golden age' whose passing Dyson mourns? For the story-tellers of the *Decameron* were gathered together by the will of the author to spend their time agreeably in a fragrant garden ('if Paradise could be formed on earth, it could be given no other form than that of this garden...', we read in Richard Aldington's translation). They not only revelled in talking; they also had plenty of exquisite wines and viands. But it was 'a feast during the plague'! Boccaccio was familiar at first hand with the Black Death, which he vividly described in the introduction to the *Decameron*. It carried off two-thirds of the inhabitants of blessed Florence. Coming from the Orient it fell on Europe like a devastating whirlwind. In half a century (from 1340 to 1388) the plague took 25 mil-

tion lives—probably a quarter of the then population of Europe.

The most appalling thing was that no one, not one of the titans of thought, was in a position to prevent the invisible killer, which eclipsed Attila and Jenghiz Khan in its slaughter.

As for Athens, it was precisely in the fifth century B.C., when the arts, science, and crafts attained their luxuriant growth, that the city was ravaged by the same Black Death. It is useful, it would seem, to recall for a moment what has become legendary: 'Externally,' we read in Livingstone's edition of Thucydides' *The History of the Peloponnesian War*, 'the body was not very hot to the touch, nor pale in its appearance, but reddish, livid, and breaking out into small pustules and ulcers. But internally it burned so hot that the patient could not bear to have on him clothing or linen even of the very lightest description, or indeed to be otherwise than stark naked. What they would have liked best would have been to throw themselves into cold water; as indeed was done by some of the neglected sick, who plunged into the rain-tanks in their agonies of unquenchable thirst: though it made no difference whether they drank little or much.' 'The doctors', Thucydides said, 'at first were helpless; they did not know how to treat the disease.'

There it is, the irretrievably passed 'golden age'! One could add to the description of the helplessness of the Asclepiadae of the day, savage scenes of the cruelty and tyranny in slave-owning Athens, for all its classical democracy, and in feudal Florence, despite its humanism, and so on. But is it worth it? It is clear without, what 'Paradise Lost' was like.

Well, and what of our present age? It is not quite like the past, of course, in any case neither Athens

nor Florence is the same. Akademgorodok near Novosibirsk? Obninsk or Dubna near Moscow? Saclay near Paris? Princeton near New York? Cosy green corners of our planet with all the conditions for creative scientific work! There is just one trouble. There is none of the constructive 'cultural isolation' or 'clannish exclusiveness' that Dyson pines so for. On the contrary, it is there that you encounter the kingdom of collective thought, continuous contacts in the laboratory and at international congresses, exchange of information on a global scale.

Even in Princeton, the quiet little university town that Prof. Dyson chose as his refuge, there is no escape from out-of-town and foreign visitors. And Princeton men, furthermore, are noted for their sociability. Ah, what a mad, mad, mad world this is! The point, you see, is that there, in the shade of the Princeton chestnuts, Prof. Dyson had a bright idea—humanity must undertake a search for the past in the future. Where better than out in space, he says, to go back—to the conditions of prehistoric times.

Please note, however, that in striving for a different intellectual atmosphere à la Dyson, who suggests colonizing asteroids, it is not necessary to cry 'A rocket, my kingdom for a rocket!' The rebellious spirit of the trail-breakers can find self-expression on our planet, too. Apart from the bowels of the earth and the depths of the sea the surface of the continents, including both the Americas, is still very much 'terra incognita'. How much around us is still uninhabited, uncultivated territory, even wild, unexplored, primaeval corners! And how many people still live in conditions not fit for human beings? It is difficult to believe, but it is the sad truth, that around 300 million of our fellow-beings drag out a wretched, semi-savage existence not yet having advanced beyond

the stage of primitive society (which is ten times as many as during the Stone Age!).

Why not spread oases of culture there? Give them their own Princetons and Florences? The work of putting our house in order would probably take more than a century. And if one is to blame scientific and technical progress, surely it should be because it isn't changing our world fast enough rather than because it is changing it too fast.

There is no doubt that this immense transforming activity has always had its shortcomings and probably always will. Fire, from the very time it was tamed by our forefathers, right down to the present, not only gives warmth and heat but burns too fierce, and causes conflagrations. But who would take it into his head to renounce it on those grounds?

Any discovery or invention, from flint and steel to nuclear reactor, from the wheel to the sputnik, can be used for evil as well as for good, for destruction as well as for happiness. So it has been since time immemorial. But isn't our day and age better and more beautiful than the past? Doesn't the good that scientific and technical progress brings us outweigh the evil?!

That, of course, should not generate complacency; not everything, in fact far from everything, has yet been done to reduce the possible harm to the minimum, or in order to foresee and counter the negative consequences of scientific and technical progress. But that is no reason to give way to hysteria, to sow panic, and to pronounce an anathema on scientific and technical progress, as some authors do.

The life of mankind, like the life of man, is unthinkable without sacrifices. But the paradox of sacrifices is that they are made for the sake of something even more dear; the loss is repaid by the gain.

The rapidly mounting flood of discoveries and inventions dulls our feeling of amazement at the achievements of human thought sometimes embodied in the simple, most ordinary things around us. We take for granted things that would have seemed fantastic to our grandfathers. Involuntarily one recalls Stefan Zweig's reminiscences in the preface to his *Voyage of Magellan*, in which he confessed that the stimulus to work on the book came to him from a feeling of shame.

'... The monotony of the ship's routine had become insufferable,' he recounted of his voyage on a transatlantic liner. 'This fine, comfortable, swift steamer was steaming far too slowly for my taste . . . "Here you are," I said to myself, "travelling in the safest of ships upon the loveliest voyage imaginable, with all the luxuries in the world at your disposal. If you find it chilly in your cabin after sunset, you need merely turn a switch and the air is warmed. If the equatorial sun is too hot for you at noon, in two or three strides you can go to the cool, shady room where the electric fans are kept working, and a little further on you can plunge into a swimming pool.... You are given both ease and safety. . . . Remember, impatient and ungrateful as you are, what voyages were like in the old days. Compare your present experiences with those of the valiant navigators who were the first to cross this ocean, and to make the world known to us. . . . Try to picture how they set forth, on ships little larger than fishing-smacks, to explore the unknown. . . . For months, years, no one at home knew what had become of them, any more than they themselves knew where they were going. Want was their fellow-passenger; death in myriad forms environed them by sea and on land. . .".

'As soon as I began to recall the early voyages of



the conquistadores of the sea, I was thoroughly ashamed of my impatience.'

That long quotation was worth citing if it pricks the conscience of those who do not see the immense improvements brought about by scientific and technical progress, or who consciously or unconsciously adopt Pythagoras's precept μηδεν θαυμαξειν! (To wonder at nothing, or 'wonder not, nor admire not in thy mind,' as Shakespeare put it.)

Zweig's historical parallel cannot be bettered; how better to represent progress than as a ship, built to sail forward, stubbornly holding its course to distant shores amid waves and reefs, not to lay up in sheltered bays but to set out again and again for new paths and horizons, new quests and discoveries—for the essence of progress is onward movement. This symbolic 'transport parallel' can be continued without difficulty to illustrate the most historic advances.

On 6 December 1522 the dilapidated hulk of the galleon *Vittoria* limped into the Spanish harbour of San Lucar de Barameda. On board were a handful of emaciated seamen, who resembled living skeletons. 'From that anchorage, three years earlier, under Magellan's leadership,' we read in Zweig's account, 'two hundred and sixty-five men had set sail. Now one ship, manned by eighteen survivors, was returning to the home port. . . . People stared at them as if ghosts from the tomb. . . .'

To the rejoicing of the victors—'We have returned! We have done what no one ever did before us! We are the first circumnavigators of the world'—the organizer of the voyage, alas, could not add his voice. Magellan had died on the eve of his triumph; but his name and his feat have survived for centuries.

Four hundred and forty years after Magellan, on 12 April 1961, it took only one hundred and eight minutes to circle the planet on the spaceship *Vostok-1*. When the rocket engines, with a power of 20 million horsepower, were fired on the launching pad at Baikonur, Yuri Gagarin pronounced his famous 'Well, we're off!'. That was at 9.07 Moscow time. At 10.55 Cosmonaut No. 1 had landed in the vicinity of the little village of Smelovka near Saratov.

His place in history was *hors cóncours*, the British Press wrote. He was the first man in space, the first to return and tell us the fantastic tale.

And then—do such accidents have to happen!—he did not return from an ordinary training flight in a jet aircraft, the Russian lad who astounded the world, whom the authors of several obituaries compared with Icarus.

The sky called him imperiously, but was it so inevitably a 'fatal' call? Does the irrepressible striving of people for new heights, for unknown expanses, for

intoxicating speeds really mean that a gloomy prospect of doom inevitably opens out before all science-inspired humanity? Does the tragic end of a few individual aviators, or cosmonauts, or other heroes, really serve as a continuation of Bertrand Russell's pessimistic allegory?

Did the death of Magellan, and not his immortal exploit, really symbolize progress? As a result of the great geographical discoveries, 'at one stroke,' Engels wrote in *The Origin of the Family*, 'the size of the world had increased nearly tenfold. . . . And the thousand-year-old barriers set up by the medieval prescribed mode of thought vanished in the same way as did the old, narrow, barriers of the homeland.'

G. W. Richman, member of the St. Petersburg Academy and colleague of Lomonosov, was killed by lightning while studying the nature of electricity. Of course, we could concentrate our attention on that lamentable fact if we wished and not on the invention of the lightning conductor, of galvanic cells and batteries (Volta's 'pile'), Petrov's arc, Yablochkov's candle, the welding apparatus of Barnardos and Slavyanov, dynamos, electric motors, transformers, etc., etc.

There has always been self-sacrifice for the sake of others, and always will be, because there has always been, always is, and always will be, an element of risk in any big beginning, in penetrating the unknown, in following unbeaten paths, in laying new roads to the future.

In January 1967, through an accident during a simulated launch, fire broke out in the capsule of an American *Apollo* spaceship; but *Apollo* craft have now landed men several times on the moon and brought them safely back to earth.

In April 1967, just two jumps from earth, Vladimir Komarov, commander of the spaceship *Soyuz-1*, lost his life in the cause of science. But *Soyuz* craft have since triumphantly returned more than once from orbiting the earth.

'We know that our path is hard and thorny, but we have never doubted the correctness of our choice and are always prepared for any flight, however difficult,' Soviet spacemen publicly declared on the day of mourning in July 1971 when the Soviet Union bade farewell to their comrades George Dobrovolsky, Vladislav Volkov, and Victor Patsaev, who had been prematurely snatched from us in the course of their duty. By their record flight that lasted 24 days and their investigations carried out on the world's first orbital station *Salute*, those three Russian lads wrote a new page in the history of astronautics.

But life continues in spite of death, and to spite death. 'We express our firm conviction that what happened cannot hold up the further development and improvement of space equipment and the urge of man for cosmos, his striving to know the secrets of the Universe,' the Soviet spacemen wrote. 'Onward to new launches into the limitless world of the stars!'

And they recalled the words of Tsiolkovsky: 'But, taught by history, we must be courageous and not abandon our endeavour because of failures. We must discover their cause and eliminate them.'

The air crash that robbed us and all humanity of Gagarin occurred in March 1968. A few months later, in December 1968, the testing of the 120-seat Tu-144 jet liner, the first supersonic passenger aircraft, began. Its cruising speed is 2500 kilometres an hour (twice the speed of sound), its ceiling 20 000 metres, its cruising range without landing nearly 7000 kilometres.

Now civil aircraft resemble supersonic aircraft, even spaceships, in their parameters!

The Tu-144 is fitted with every conceivable device to ensure the safety of the test pilots. Every vital system is not simply 'insured' by a 'double', like the pilot by the relief pilot sitting beside him, but has quadruple reserves of reliability. The skill of highly experienced airmen who are masters of their job is supplemented by fast-acting automatic devices. A built-in computer can calculate the optimum trajectory, maintain a given course, turn the aircraft and make the landing approach, even 'blind' in fog.

Reliability, reliability, and again reliability,— that is the slogan of all the vast work that has been put into the Tu-144 by its makers. It has become the rule for all our aircraft constructors and designers, and not just for those who build supersonic planes. And we can be certain that the engineering will not let us down, will not fail us, wherever we meet it, in the sky or on the ground.

But will the rise in transport speeds frighten us rather than delight us? It is said that by the year 2000 passenger liners carrying 2000 passengers will be flying on the air lanes at speeds of 12 000 kilometres an hour. Aircraft constructors are thinking in terms of rocket planes capable of flying at heights of 90 000 to 100 000 metres and developing speeds of 25 000 kilometres an hour.

In his *The Aeronaut's Tale*, Leo Tolstoy wrote: 'In the first minute I began to be frightened and ice ran through my veins; but then, suddenly, my spirits brightened and I forgot to be afraid.' Quoting him in an article about the testing of the Tu-144, writer Anatoly Agranovsky noted: 'We all forget to be afraid; that is true, and has been proved many times. And we forget to marvel, and that is a shame. One must

marvel'. Yes, in our world, there is something worth marvelling at, it deserves raptures.

The Tu-144 can cover the distance from Moscow to Khabarovsk (8500 kilometres) in three or four hours (by ordinary jet it takes eleven hours). So that, having visited the Far East, you could return to Moscow the same day. That means, by the way, that, having had lunch before landing in Khabarovsk at twelve noon local time you would need to prepare not for supper in Moscow, but for breakfast or a second lunch, because you would be back there again not in the afternoon, but in the morning of the same day. Outracing the sun in its movement across the sky, the new supersonic aircraft will bring us all, and not just a few individual bold spirits, closer to cosmic speeds, changing our views of time.

The men on the first round-the-world voyage detected an unusual discrepancy. According to the ship's logbook, which had been kept very carefully, it was Wednesday when in fact it was already Thursday. Somewhere they had lost a whole day! The 'loss' represented a real discovery for science, a new truth that stunned everybody, because no one, not even the greatest thinkers, had suspected it. As a result of this discovery an innovation came about that is now a commonplace; a line for changing the date—the International Date Line—was established, running down Bering Strait along the meridian.

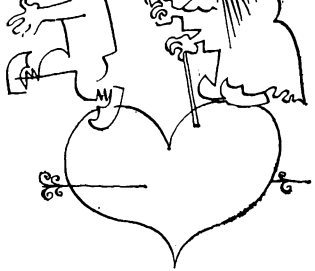
Today there are few who marvel when cosmonauts cross the 'date line' several times in the course of a day's flight. Yet there is undoubtedly an element of the unusual in that, too. For the periodicity of our life, our being used to the natural succession of day and night is fixed in the physiological mechanisms of our organism and its daily biological rhythms, which resemble a well regulated clock in their punctuality.

That immemorial rhythm is being broken more and more often by cosmonauts. On other planets, people would experience days and years of another length. And very likely their 'biological clocks' would need to become attuned to new rhythms.

So it looks as though we shall have to reckon not only on new corrections to the calendar and arbitrary 'time shifts' connected with a new style of dating or a new date line, but also on something else.

An amazing conclusion follows from the theory of relativity, that all physical processes during a cosmic flight, including the movement of the hands of a clock and the ageing of the organism, will occur more slowly than on earth (from the point of view of an earthly observer).

Imagine two Earthlings of the same age, a boy and a girl, both aged twenty. Let's call her Solveig and him Per Gynt. Suppose they have to part, he on a non-stop, return cruise to the star Arcturus at a speed 99 per cent of the maximum possible, i.e. of the speed of light. He will be homebound only after many years, when he is 32. By all earthly laws patient long-suffer-



ing Solveig, at the time of meeting, will be 80 years old, no more and no less. Quite an old woman. But not Per Gynt! He won't be at all old. A drama fit for the pen of Ibsen himself.

Joking apart, it is theoretically possible, and actually not excluded, that a case could arise when an astronaut, who becomes only a few years older during a flight at speeds close to that of light, may, on returning home to our planet, meet his great-great-great-grandsons, separated from his long dead coevals by hundreds of years.

Do you recall our story of Peter the Great's reform of the calendar? It converted the year 7208 into 1699. The change of epoch was purely arbitrary. It happened 'on paper'. A little more than two centuries later it appeared that such a time shift was really possible and was the reallest of realities.

The possibilities are still regarded as purely hypothetical, of course. But didn't the work of Tsiolkovsky, Kondratyuk, Zander, Korolev, and other pioneers of astronautics, seem very hypothetical to their contemporaries?

At the beginning of 1939, only three years before the first uranium 'pile' went critical, Niels Bohr listed 15 weighty arguments excluding technical utilization of nuclear fission.

And the possibility of obtaining the induced radiation predicted by Einstein in 1918 did seem a purely hypothetical possibility, did it not? But today it has become reality. Through the work of A.M. Prokhorov and N.G. Basov (now members of the USSR Academy of Sciences) and their American colleague, Prof. C.H. Towns, quantum generators have been developed that emit this radiation, remarkable instruments that now find wide practical application.

Turn your mind to this idea: what has become the

period for the practical introduction of what seem the most abstract scientific discoveries?

Man had his first encounters with electricity and magnetism thousands of years ago. Their close relationship, the fact that they are different aspects of a single, more complicated phenomenon, was only established in the first third of the nineteenth century. From the time when Faraday observed electromagnetic induction (1831) it took more than 40 years for his discovery to find industrial application; only in 1873 was the first technically advanced dynamo built, while the first electricity generating station was built only in 1882.

More than 100 years passed before the principles of photography found practical application (1727-1829); more than half a century for the telephone (1820-76); nearly 35 years for radio (1867-1902); about 15 years for television (1922-36) and radar (1926-40). The period gets steadily shorter and shorter; it took only six years to develop atomic weapons (1939-45), even less time, five years, for transistors (1948-53) and lasers (1956-61). There it is, the time gain that is transforming our epoch and all our lives!

Man is not only acquiring power over matter and space, but is also mastering time, Time itself that not so long ago seemed something absolute, completely independent of us and not susceptible to our will.

Thus, the 270-odd years that have passed since Peter the Great's reform 'shifted' time by five and a half thousand years are in fact a gigantic time if we measure it in milestones rather than centuries, in the milestones of scientific and technical progress. But is it only a gigantic period in terms of scientific and technical progress? What about social progress?

The year 1700 is not simply a nice round date. For Russia, the dividing line between the two centuries

proved a kind of Rubicon, after which a period of important reforms began that left a deep impress on the political, economic, and cultural life of the country.

It must also be said that the eighteenth century became a turning point for more than Russia. It was then that the industrial revolution began, continuing on into the nineteenth century, and transforming the face of the world. As Karl Marx put it, large-scale industry for the first time created world history, wiping out the former, naturally conditioned isolation of the separate countries, and creating a world market and system of communications.

The end of the eighteenth century was marked by one of the greatest events in world history, the French bourgeois revolution, which, overturning the creaking coach of feudalism, raised the tollgate before the fast, powerful locomotive of capitalism.

The 'locomotive of history' drove on ahead at full steam. And it must be said that the bourgeoisie were very aware of the milestones of progress flashing by them; and were deeply moved by them because they attributed all the advances of social, economic, scientific, and technical progress to their own beneficial influence.

Here is an interesting touch. In order to stress the unprecedented historical character of that great turning point, the French Revolution, the National Convention adopted a new calendar. The day when royal power was overthrown in France, 21 September 1792, became the last day of the Christian era, and 22 September 1792 was transformed into the First Vendémiaire of the First Year of the Republic. Time, too, was reformed. Henceforth days were to be divided into ten equal fractions instead of 24. Clock faces were to be given ten divisions instead of the customary twelve, and each of them was to be divided in turn into ten (instead of sixty) minutes.

Clocks were an expensive rarity then, of course, and the new measure of time, which required their alteration, was not widely taken up. The new chronology was altered back in 1805 by Napoleon who, by agreement with the Pope, returned the 'lost people' to the good old Christian era, putting them back, as it were, on the path of truth (the previous year he had restored monarchy in the country, proclaiming himself emperor).

It is not given to everyone, however, to turn history back, to change its laws, or to stop the course of time.

'A spectre is haunting Europe, the spectre of Communism...' with those words began a little pamphlet published in German in London in 1848 and republished in the course of the next hundred years in around a thousand editions in 77 languages. Modest in appearance, it concealed a charge of ideas of prodigious explosive force. It was *The Communist Manifesto.* In it its authors, Karl Marx and Frederick Engels, set out in clearly written and strictly scientific form the inexorable logic of social progress, which even the most penetrating historiographers and social scientists had not seen.

Just as the system of primitive communism had passed into the slave system, and then into feudalism, overthrown in turn by the bourgeois system, so capitalism would inevitably be replaced by socialism, which the proletarian revolution would usher in. The God-ordained and defended world of bourgeois prosperity could not believe its ears; it, the flourishing, enlightened fulfiller of radiant hopes, was sliding down, it seems, to inevitable doom because it had created its own grave diggers, the proletariat!

As the course of world history has confirmed the Marxian conception of social development, the idea of progress, both social and economic, and the scientific

and technical progress closely linked with it, has dimmed in the eyes of the apologists of the doomed system, giving way to hopeless pessimism and apocalyptic revelations. It gets worse and worse. Calls ring out for 'a halt to progress', 'to check the scientists', 'to turn back', and so on and so forth.

All the current tirades against progress, even the very latest, have a musty, mothball smell, old as the world. 'In much wisdom is much grief, and he that increaseth knowledge increaseth sorrow,' one of the maxims of *Ecclesiastes* has it, that collection of sayings that churchmen consider the quintessence of Biblical wisdom.

'Blessed are the poor in spirit,' echoes the New Testament. The Gospels became the banner of militant obscurantists, of the 'crusade' against the 'bookmen'. The Metropolitan of St. Petersburg advised the Czar to exile I.M. Sechenov 'for humbling and correction' to the Solovets Monastery on an island in the White Sea near Archangel for having published his *Reflexes of the Brain.*

The lay sovereigns did not lag behind the Church rulers. The Russian Emperor Alexander I is famous for having tried to extirpate the hateful (to him) word 'progress' from the brains of his subjects. But in vain!

The atmosphere of reaction that prevailed in Russia in the nineteenth century was vividly described by Saltykov-Shchedrin. In his *Diary of a Provincial in St. Petersburg* the great satirist sketched the figure of one Lt.-Col. (retired) Sdatochny, who had worked out a project ('For the Reformation de Science Academie') in which he proposed compelling citizens to write a composition on the theme 'Ways for the Complete Abolition of Science', taking into account that the State should suffer no loss by it and afterward should hold its neighbours in such fear that they would es-

teem it above all for its high degree of enlightenment.

Nicholas II, the last of the Russian autocrats, to whose liking the word 'intelligentsia' did not appeal, threatened to command the Academy of Sciences to expunge the word from the Russian dictionary.

The Russian people expunged the name of Nicholas II and the word 'autocracy' from the lexicon of the future, along with many other synonyms of the past; and in doing it the Russian proletariat and peasantry were aided by the progressive intelligentsia.

The French revolutionary and atheist Pierre Sylvain Maréchal (on whose initiative the first French Republic adopted its new calendar) wrote in his time that the French Revolution was 'only the forerunner of another, greater and more majestic one to come'. The beginning of that new revolution was heralden by the salvo of the cruiser *Aurora*.

As soon as the Great October Socialist Revolution was made the newly born Soviet Republic ordained, by special decree, the dating of all events according to a new style (the Gregorian calendar) 'in the interests of establishing in Russia the same reckoning of time as is used by almost all civilized nations.' And after 31 January 1918, came not 1 February, but 14 February 1918. And that was all. There were no pretentious innovations, although our Revolution opened a new era for humanity. 'To us,' wrote Lenin, 'has fallen the good fortune to *begin* the building of a Soviet state, and thereby *to usher in* a new era in world history. . . .'

It was then that capitalism for the first time experienced the titanic strength of its grave diggers. The ageing system had its first heart attack. It suffered another stroke after the Second World War, when other countries joined the socialist camp. The physicians-in-ordinary of imperialism were alarmed; history had

shown them the 'maw of death'. Isn't that why the bodyguards of the moribund system are ready to veto progress? Denying the objective laws that govern the development of society, they represent the past as a chaos of chance, a dismal labyrinth from which there is no way out, even in the future, and where humanity will inevitably fall into the clutches of the Minotaur. In terrifying mankind with the nuclear Minotaur, the new prophets of doom deliberately forget that the atomic bomb was first used by imperialist America against imperialist Japan, which had attacked the USA, and that the Second World War, like the First, was unleashed by imperialists.

Why should we consider scientific and technical progress dangerous *per se*? Isn't it rather a matter of whose hands control it?

The advances of science and technology in the USSR have demonstrated the potentialities of the new system to the whole world. Now, as never before, it has become clear how great is the role of social progress; it is under socialism that it is able to exert the most beneficial influence on scientific and technical progress, which in turn proves a powerful lever for further improvement of various social institutions for the good of all society.

For some time, however, many bourgeois philosophers and sociologists have begun talking hopefully of the present developing scientific and technical revolution. G.I. Gerasimov, political commentator of the Novosti News Agency, has given three reasons for this turn to optimism. 'First,' he wrote in *Kommunist*, 'the political struggle has put on the agenda an item about the path of development of countries that have won political independence. You don't win their adherence with a sour face. Secondly, many honest, though confused, scientists and politicians have been

turned into pessimists and sceptics criticizing capitalism, albeit inconsistently, for its inhumanity, so that it has become necessary to isolate them. And thirdly, it would be irrational, from the bourgeois standpoint, not to try and gamble politically on the achievements of science and technology making possible a temporary growth of the economy in capitalist countries and a rise in the standard of living.'

Technical progress, the French sociologist Jean Fourastié, for example, argues in his book *Les 40 000 Heures* (meaning the working life of a person in the not distant future), is the direct key to economic advance, while economic advance is the key to social progress. From that Fourastié draws a picture of the development of a society without conflict; a single 'middle class' develops, consumption rises, the hegemony of capitalists is replaced by the authority of engineers and scientists, and the people drive about in motor cars or watch television and lose interest in politics.

No wonder prayers are heard more and more often for the health of scientific and technical progress, as well as anathemas.

While some writers terrify mankind with a 'machine hell', others promise us a 'machine paradise'. Opinions on the state and prospects of scientific and technical progress are so diverse as to be at times diametrically opposed. Does one need to demonstrate how important it is to understand the essence of such a complicated phenomenon?

We know that scientific and technical progress is closely linked with social progress. And the driving force of social progress is the development of the productive forces of society, which include science and technology. But what is science? What is technology? What springs drive their development?

We in the Soviet Union say that science is becoming

a direct productive force of society. But since when? And what does it mean?

We are used to the idea that we live in a period of scientific and technical revolution. But what lies behind it? When did the process begin? How does it proceed? And what is it leading to?

We all intuitively understand that the present era of scientific and technical progress is not quite the same as the past age. But what does the difference consist in, precisely?

That is the question that forces us to look back so often. Study of the past helps us to understand the present better, and so to predict the future more confidently, the future that is already being shaped now by our hands and our brains.

One of the main problems that comparative historical analysis helps us to resolve is the finding of objective criteria enabling us to reduce subjectivism to a minimum, if not to eliminate it altogether, in our approach to scientific and technical progress. What should we take as our basis for comparing the past and the present? Can we find some strict, perhaps even quantitative, standard by which we can express a definite trend in scientific and technical progress with complete accuracy?

In our assessments we shall certainly mention the tempos of scientific and technical progress and speak of their acceleration. That is an aspect of the phenomenon of no small importance, so we propose to begin with it.

The Metronome of History

'"Time is money," the English say, and pay their tailors and bootmakers with it instead of cash.'

So, as I recall, Chekhov joked about the classical formula of bourgeois philosophy. And how right he was!

Who do you think put that saying into circulation? The great eighteenth century American scientist, Benjamin Franklin, who was not an economist, of course, but a physicist. This revealed truth of mercantilism springs from the aphorism of another scholar, the Greek philosopher Theophrastus (fourth century B.C.): 'Time is the most valuable thing a man can spend'. There are many such winged phrases. They are evidence that people have been conscious since days of yore how much the time factor means.

But what has that to do with the concept of progress?

'Men have long sought means to save time,' says the Soviet philosopher V.G. Afanasiev in his book *On Intensifying the Development of Socialist Society*. 'With the aim of obtaining the greatest quantity of material and spiritual values they have striven to lighten their physical, and then their mental exertions.

So *technology* was born by which man learned to win from nature the means he needed for living, in ever greater quantities and in ever shorter time. And under pressure mainly of productive, technical consumption, *science* arose, a system of knowledge and of how to obtain and apply knowledge, and that system finds its practical embodiment in technology.'

Let us recall Karl Marx's remarkable expression in his manuscript notes on *Capital from Money*: '...For both the separate individual and society the comprehensiveness of their development, of their needs and their activity, depends on the saving of time, and boils down to economizing time.'

Afanasiev explains the significance of that profound remark of Marx's for our time, as follows: 'The latest scientific and technical revolution and control of social processes now emerge as most important means for intensifying the functioning and development of society and as a means of saving time.'

'Intensification'—we shall be hearing and repeating that word more and more often. Have you ever tried to get to the root of it?

But is there anything to philosophize about here? Or is 'intensification' simply an increase in the intensity of some process or other, and nothing more? 'But this term has acquired a broader meaning in the social sciences,' Prof. Afanasiev explains. 'It means not only an increase in the intensity of social processes and a rise in their rates of development but also a striving by people to achieve better results in their economic, social, and intellectual life in the shortest possible time. *Saving time is the very essence of intensification.* Intensification, that is to say the degree to which time is saved, is the main index of the state of any society and of the level both of its all-round development as a whole and of that of its individual members.'

So that is what time is all about! At first glance the word itself even has a dying fall, putting one in a contemplative mood: eternity, infinity, permanence. How much more energetic and dynamic 'tempo' sounds! Quite another music, quite another sense, is it not, although its literal translation from the Latin is just 'time'? Let us take this concept as our starting point to try and find a measure for historical change that will reveal the dynamics of scientific and technical progress.

So far our historical excursions and parallels have given a feeling of sharp contrast between times past and times present, contrasts that testify in favour of the changes distinguishing our Today from our Yesterday and giving hope of a better Tomorrow, but contrasts that have hardly left any integral impression of the many planes of the historical panorama. The main point is that they have not yet become the basis of a scale that would help us to evaluate more or less exactly the size of the leaps already made and that will be made subsequently, in order to assess more precisely the shape of things to come.

'Scale' means a 'ladder' or 'staircase'. Each rung or step (or division in our case) is a period of time. Let us try to represent the step-by-step ascent of man in this march of time.

It would be better, of course, not to see the picture statically like a still photograph but in movement as on the cinema screen. And why shouldn't it be made to appear to move, to appear as continuous development, by taking separate, momentary pictures made in various historical periods? Cinematographic movement, as you know, is built up from a set of stills, from bits, or individual frames, that taken separately are nothing but 'frozen moments'. Can't we do something the same? Isn't it possible to find very characte-

ristic 'frames' of some sort in the annals of history? Let them be rare, divided by big intervals (say 270 years) but such that they constitute a single series (not a haphazard collection) and combine into a kind of newsreel of progress.

The next step is to attempt a precise evaluation of the change in one and the same object from frame to frame.

The results of the changes could be plotted as dots on graph paper in such a way that the distance between them along the horizontal corresponded to the historical distances and the height of each point indicated the level of progress according to a definite index.

And finally, the last step would be to draw a continuous line or curve through the points so that the separate discrete dots were transformed into an unbroken sequence. Beginning somewhere in the Dark Ages it would traverse the whole of the past and break off in the present. But now, knowing its trend or curvature on all sectors of yesterday and today, we could continue it into the future and so plot points in the picture of tomorrow. That, in any case, is more or less the method of extrapolation that is sometimes employed, not without success, in making forecasts.

Only what are we to take as our time interval? And what should the index of change be?

Going back 270 years we saw that the period from 1700 to the present was immense, that it covered a great many events that have altered the face of the world. But surely the 270-odd years before 1700 were also not a very short period! For they, too, were the same as 100 000 days or 2 400 000 hours.

The same, and not the same. Let us compare the two intervals—the 270 years since 1700 and the 270 years before that, which would take us back to the first third of the fifteenth century.



In 1404 clocks or 'hour measurers' first appeared in Moscow. 'Self-moving and self-ringing' they seemed veritable marvels of technique to the chroniclers.

What in fact were they like? Huge weights on chains, a wooden disc with Slavonic letters instead of numerals, and beside them, under an arch, a bell. There were no hands; the dial itself turned. The Kremlin clock remained more or less like that in the fifteenth century, throughout the sixteenth century, and right into the seventeenth. In the 1620s it was replaced by an improved, better clock built by a family of Russian craftsmen, Zhdan, his son Shumila Zhdanov, and his grandson Alexei Shumilov, under the direction of an English master clockmaker, Christopher Galloway.

The new marvel of technique had the same revolving dial with a single hand fixed immobile to the tower. But now, as well as Slavonic letters, there were also Arabic numerals, seventeen of them rather than twelve. For in Russia then they told the time differently during the day (from sunrise to sunset) than during the night. And since the length of the daytime changed from one day to the next, sooner or later the difference would be very noticeable, even on Galloway's clock,

on which the smallest division was the 'half-hour'. Shumila Zhdanov made the corrections needed with tireless concern for accuracy. Grasping the back of the five-metre oak dial he turned it to the new nocturnal or daytime schedule. The sun's rays, as they faded or lit up the golden weather vanes of the Kremlin spires, signalled the exact time. In cloudy weather, as you will realize, there was nothing for it, for the high priest of grey Chronos, but to rely on his intuition, on the sixth sense of the Czar's clockmaker.

A contrast will also be noted, of course, with the beginning of the eighteenth century. But what a contrast there is between the eighteenth and the twentieth centuries!

Today, as for centuries past, the sound of the Kremlin chimes is regularly heard from the clock in the Spassky Tower. But the permissible daily error of the clock has been reduced to millionths of a second.

The watchdog of its accuracy is the USSR State Time and Frequency Standard. Screened in the quiet of a forest from the hurly-burly of Moscow, it is guarded against interference in specially equipped underground premises. There, in the instrument hall, in a world of perfected mechanisms, are unusual 'grandfather' clocks, 'ticking' soundlessly without weights, without chains, without springs or hands, atomic clocks. The role of the pendulum is played by microparticles of a substance that oscillates at an incredibly high but amazingly constant frequency. These devices only deviate by one second in 300 years. The special services that broadcast the Moscow radio time signal check their instruments by them.

Time is being compacted, as it were, becoming more and more saturated with significance; and each twinkling proves more and more valuable. A twinkling, if we recall the original meaning of the word (the time

taken to blink an eye), will be about 0.5 second long. Once the word 'instant' was associated with a barely perceptible, infinitesimally small interval of existence that could safely be ignored. But not today.

The Tu-144 flies 350 metres in half a second. It moves about 80 times as fast as a horseman riding at full gallop. But a spaceship can fly dozens of times faster than a Tu-144. And a delay of half a second in switching on the braking engines can cause significant divergences from the planned landing point.

An instant in the twentieth century is an inch of cinema film flashing before the eyes of viewers; it is the hundreds of luminous lines traced dozens of times on the screen of a television tube by its electron beam. It is the 130 000 revolutions completed by a bundle of protons in the 1.5-kilometre ring of the 70-GeV Serpukhov accelerator. It is the 500 000 operations performed in the 'brain' of a fast electronic computer. Need we continue? In our 'fast-acting' world even a second frequently proves too coarse a unit of measurement.

And that doesn't apply solely to the 'second nature', as Maxim Gorky called the world of things created by man. Objects of natural origin, at every level from atomic particles to stellar systems, when they become accessible to human consciousness, have made rigorous demands on the most exact chronometers.

In recent decades elementary particles that exist for only one ten thousand millionth of a second (a tenth of a nanosecond) have been discovered. And strange as it may seem they are counted as long-lived! For when they are born they actually have a 'whole eternity' in reserve compared with the fleeting little interval of time in which the fastest known movement (the propagation of light) crosses the shortest conceivable distance (the diameter of an elementary parti-

cle). That interval is 10^{-23} second (a fraction with 23 zeros in the denominator), and is considered the minimum interval on the time scale that physicists will ever be concerned with. But how long ago was it that the smallest 'moment' of time that suited everyone was a minute?

You haven't forgotten, have you? The Moscow clocks did without minute hands for three whole centuries, and only got them in 1704 together with new faces made 'in the German fashion'. The Germans themselves, incidentally, and other West European nations, had only had this innovation a short time themselves. Minute hands came into use at the end of the seventeenth century and second hands at the beginning of the nineteenth.

Wasn't the increase in the number of hands on clocks, and the need to divide the natural diurnal rhythm into ever smaller fractions evidence of the growing scale of the changes in the world around us, of the greater saturation of the unit of time with events?

Here is a rough but striking analogy. Let us imagine the 600 000-year road travelled by mankind as a 60-kilometre marathon. And let it be recorded on a film that lasts an hour, showing one kilometre each minute.

The road begins in Stygian gloom (in a cave) that is gradually lit by the first campfires. The first to tread it are *Pithecanthropus* (apeman) and his cousin *Sinanthropus*. Their number is a million or so. In their hands are sticks and roughly chipped stones. Somewhere along the second half of the road the relay is taken up by Neanderthal men, more highly organized creatures (they are already called *Homo* man). Their tools are more perfected, thin stone blades and pointed bone implements. At the fiftieth kilometre Cromagnon men take over, people of our contemporary type (*Homo*



sapiens thinking man). They are not only warriors and hunters, not only craftsmen knowing how to make carefully fashioned stone tools, but also artists. At the 58th kilometre cave paintings occur, made with a mixture of soot and clay and fat. At the 59th kilometre the first domesticated animal, the dog, walks alongside man.

When only 700 metres remain to our times, agriculturalists join the hunters, fishers, and herdsmen. The former nomads settle down, and whole settlements arise (houses, dugouts, clay huts, and later log cabins and pile dwellings, and soon, 500 metres from today, the Egyptian pyramids are raised). In the houses are clay vessels. The means of transport are dug-out canoes, rollers, and then wheeled carts.

Production of food increases and population grows. Men are already numbered in tens of millions.

The first metal articles from copper and its alloys with tin (bronze) appear at 500 metres from us, and iron at 350 metres. The number of people varies between 20 and 40 million.

Some 250 metres are left. The Greek scientists Pythagoras, Heraclites, Leukippus, Demokritus, the Athens of Pericles, outstanding statesman of Hellas.

60-50 metres. The Middle Ages with a population of hundreds of millions people.

60 metres. Fourteenth century Florence and the beginning of the Renaissance.

45 metres. Magellan's circumnavigation of the globe.

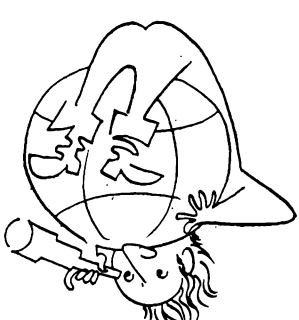
27 metres. Peter the Great's reforms in Russia.

17 metres. The steam engine. Population above 1000 million.

You can easily continue it further yourself. But notice one thing: only over the last metres of the sixty kilometres do electric lights burn more and more brightly, motors roar louder and louder, airplanes rise into the air, and space rockets take off.

The last frames of our imaginary film are so packed with events that they cannot be squeezed into it, or into a great mass of film, even if we employ multiscreens, circlorama, and stereophony. Imagine what a stream of impressions would be hurled at the poor viewer at the end of it!

An effective sound track for the viewer would be the beat of a metronome, counting out the rhythm of history as it were. For a long time we would hear the tempo known in musical terms as *largo* (very slow). After the *largo* would come *adagio* (slow), which would change much more quickly into *andante* (the tempo of



a slow march). Then quicker still it would become *allegro* (quick). There is still a fifth tempo, *presto* (fast). In music it is the final one. But if it characterizes the present age, what is there to describe the age to come? For the rate of change is accelerating!

But that is no more than a metaphor, with no pretentions to scientific accuracy. And we would like to estimate the tempo of the transformation more accurately.

Norbert Wiener, trying to take the historical perspective in at a glance in his book *The Human Use of Human Beings* (sub-titled 'Cybernetics and Society') showed that the last 400 years (only 40 metres out of our 60 kilometres) are a very special period in world history, and that this period 'during which the main conditions for the vast majority of men have been subject to repeated and revolutionary changes had not even begun until the Renaissance and the great voyages, and did not assume anything like the accelerated pace which we now take for granted until well into the nineteenth century.'

With such an approach it would seem that quantitative analysis of scientific and technical progress would be made easier. Instead of 'delving in the chronological dust of the description of life on earth' let us limit ourselves solely to the last three or four centuries.

Unfortunately our very first attempt to trace the character of the changes over the course of these three or four centuries by many indices doesn't work. What can we say, for example, about the production of electricity when we consider the eighteenth century?

Or the speed of travel and conveyance? Over the past 400 years it has increased more than a thousand-fold. The difference is appreciable, of course, but does it consist solely in an increase of speed? If we take present-day diesel, turbo-electric, or atomic ships (and

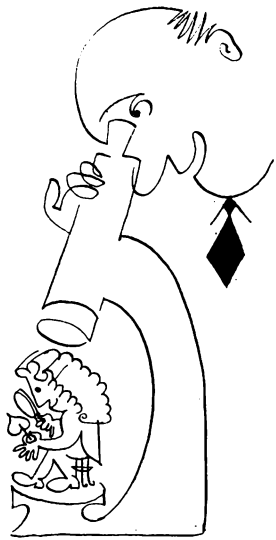
not even the fastest ones), aren't they as different from the wooden sailing ships of Magellan and Christopher Columbus as heaven from earth? But what do we mean by 'difference'? Each of us sees and compares such things or such phenomena in his or her own way through the unique subjective prism of his or her own personal perception. There are so many pairs of eyes, so many viewpoints, which ones are we to choose? Maximum objectivity is needed. The pull of figures is understandable, although Hegel was troubled by *das Rätselhafte der Bestimmung durch die Zahl* (the mystique of definition by number).

What yardstick, in fact, applies to the results of scientific and technical progress? To new ideas, discoveries, and inventions? We can't cut them on scales, measure them in kilowatt-hours or cubic metres, or simply by the piece! Perhaps we can take the change in the period it takes to master inventions and discoveries?

The American scientist Frank Lynn made an interesting study for the National Commission on Technology, Automation, and Economic Progress of the average rate of development of twenty important technological improvements. He calculated how many years it took at various periods from the basic theoretical idea to its practical application, through its incubation period to its final commercial development. What did he find? Around 37 years for 1895-1919, 24 years for 1920-44, and 14 years for 1945-64.

But alas, such figures are clearly rather few to describe so complex a phenomenon as scientific and technical progress. But all their collectors and classifiers have not given up; any quantitative index, they say, is better than none at all.

The science of science—a new discipline studying science itself by its own methods—is assembling pre-



cise statistical data on everything that has the least bearing on scientific and technical progress: the number of scientific publications in any interval of time at various historical periods; the number of new specialized journals published before and now; expenditure on the development of science and technology; the number of scientists, engineers, technicians, and personnel serving them.

Here, too, of course, the information assembled, a bit here and a bit there, proved incomplete, especially about the past. But everywhere it has been found to yield an interesting picture.

However varied the characteristics are, very many of them approximate in some degree to a mathematical law, the exponential law. In other words they grow

by the rule of compound interest. How much? It varies. Some by roughly 5 per cent. That is how, for example, the number of scientists, engineers, and technicians, specialized journals, scientific articles, expenditure on research, and production of electricity have increased, doubling every 15 to 20 years.

In other cases the doubling has happened more quickly, in ten years (number of known asteroids, literature on X-rays, speed of transport), five years (number of intercontinental telephone calls), even 18 months (power of accelerators).

However that may be, a steady, regular rise is observed in all 'parameters'. Sometimes a series persists without break over many centuries, agreeing well with the compound interest formula.

If we represent this pattern graphically, we get an exponential curve, i.e. a smooth curve rising gradually at first and then more and more steeply. It is not a parabola, nor a hyperbola, nor any other curve than an exponential one with its own characteristic features (well known to mathematicians).

The beauty of the severe elegance of this curve has fascinated many minds. It seems to offer tempting possibilities of exact, and at the same time, simple extrapolation. In fact, when the statistical data (even when incomplete and fragmentary) on the development of any field of science or technology, or any branch of industry, can be plotted as points so that a segment of an exponential curve can be drawn through them, it seems simple to find the continuation of the segment by purely geometrical means and to determine the unknown from the known, i.e. to determine from the properties of the investigated interval the curvature on any other, still unstudied sector for which exact information is not yet available (e.g. for isolated periods in the past) or for which there is still no

information in general and in principle cannot be (i.e. for the future).

That being so, why not then continue the exponential curve that begins somewhere in the depths of time and breaks off at today's date to any of tomorrow's points that interest us? To the end of the current quarter or the next quarter, year, quinquennium, century, etc.? With the essential reservation, of course, that it can be so continued. Then the results of doubling can be quickly calculated without difficulty for any period ahead!

But it doesn't always happen like that, except on paper; life is more complicated, of course, than a dead scheme. And if formal computations of this kind are taken uncritically they can have an immediately devastating effect. In fact, the results of doubling by the exponential law sooner or later become simply overwhelming.

In illustration of this there is the famous Oriental legend that, incidentally, is especially to the liking of Neomalthusians. You may be familiar with it.

He asked to have one grain put on the first square, and two on the second, and four on the third, and eight



on the fourth... and so on. And then all the heaps of grain were to be gathered together and given to him, the inventor of the chessboard.

Ah, so? Good, bring a bag and count into it exactly as many grains as he asked for, and not a single one more!

Imagine the general consternation when it was realized that the Khan's will, the will of the Mightiest of the Mighty, absolutely could not be obeyed.

On the last square of the chessboard (the sixty-fourth) they would have had to pile more grain than there had been in all the granaries of the whole world up to that time. There is no doubt that the eccentric inventor probably received his best reward from having convinced people how cruelly arithmetic takes vengeance on those who scorn its laws, who are reluctant or unable to weigh in advance the consequences of the most well intentioned decisions, or to balance their needs with their possibilities, their desires with reality, their undertakings with fulfilment and real achievements.

Arithmetic is a good thing, of course. But can't we do without it in estimating the present or predicting the future?

Social Arithmetic and the Algebra of Political Economy

In 1798 a pamphlet appeared in England entitled *An Essay on the Principle of Population.* Its author Thomas R. Malthus, a parson, but at the same time a professor of political economy, soon became world famous.

Mankind, he wrote, multiplied in geometric progression: 1, 2, 4, 8, 16, 32, 64, 128, 256, and so on (a series represented by an exponential curve). The production of foodstuffs follows another course, arithmetic progression—1, 2, 3, 4, 5, 6, 7, 8, 9, etc. (which, when plotted on a graph, gives not a curve but a straight line). If the present ratio between the number of mouths and the amount of food were taken as unity (1 : 1), it would be greatly altered for the worse in two centuries (256 : 9), and in three centuries would become something quite terrible (4096 : 13). Thus spoke Malthus.

Population would double every 25 years, according to Malthus. And agricultural production? It would also increase steadily, but more slowly, doubling first in 25 years, then in 50 years, a third time in 100 years, a fourth in 200 years, and so on.



Malthus claimed that England was already overpopulated; and that by 1950 there would be 704 million persons but only enough food for 77 million. In fact the number of Englishmen rose to only 51 million by that time, and in general they were better fed and lived better on the average than their eleven million ancestors 150 years earlier.

But perhaps England was an exception? 'From 1850 to 1950 the development of society has directly contradicted Malthus' pessimistic forecast,' writes the West German economist Prof. Fritz Baade. 'Population doubled in that time, but the production of food rose 2.5 times... Malthus' theory has proved mistaken.'

Let us take it that the doubling of world population has not occurred in geometric progression. The period of doubling has not remained constant, and has altered,

but has nevertheless proved much longer than calculated by Malthus; once it took 200 years (1650-1850), then a hundred (1850-1950). Now, on the UN forecasts for 1965-2000, it has been reduced to 35 years.

I.S. Shklovsky, Corresponding Member of the USSR Academy of Sciences, has shown that the real dynamics of population over past centuries are expressed not by an exponential curve but by a hyperbola. Staggering consequences follow from that; if the world's population multiplied further in strict accordance with such a curve, it would be infinite by the year 2030. Which is clearly absurd! It means that the tempo of growth must of necessity fall. In other words, it will break with the former pattern and become governed by some new, quite different one.

Arithmetic progression also does not fit agricultural productivity. Food production has exceeded population in rates of growth.

From what we have said it should be clear how premature it would be to elevate Malthusian calculations to the rank of a universal law allegedly governing the destiny of human society with fatal inevitability. For history has given the Neomalthusians an object lesson. It would be ridiculous, of course, to ignore the problems created by the present 'population explosion'. If only because it cannot continue indefinitely; the size and mass of our planet (which also means the quantity of food, power, and other resources) is limited.

'There is, of course, the abstract possibility that the number of people will become so great that limits will have to be set to their increase,' Frederick Engels wrote in a letter to Kautsky on 1 February 1881. 'But if at some stage communist society finds itself obliged to regulate the production of human beings, just as it has already come to regulate the production of things,

it will be precisely this society, and this society alone, which can carry this out without difficulty.'

As for specific forecasts, it would be naive to set great store on the omnipotence of any 'universal' mathematical law, whether exponential or otherwise. What is needed is a concrete, historical approach, analysis of the concrete social and economic conditions.

If we base ourselves on today's 'statistics of empty stomachs' (and they are indeed sombre, for there are now more than 2000 million people who are chronically underfed), 'the growing surplus of hungry mouths' (recall Paul Ehrlich's prophesy) is truly frightening. But each new generation, is it not also new working hands?

It is clear that man does not become a worker in his swaddling clothes but only after growing up and being trained. In addition, he has to retire sooner or later, and remains a mouth all the rest of his life. Nevertheless, as Engels said in his *Outline of a Critique of Political Economy*, Archibald Alison (1840) put forward 'in opposition to the Malthusian principle the fact that every grown man can produce more than he himself consumes, a fact without which mankind would not be able to multiply, and would not even be able to maintain itself, otherwise what would the rising generation live on?'

There is no doubt that the problems arising from the growth of population have not yet been taken off the agenda. But ways of solving them are suggested by the whole experience of building socialism. To take the USSR as an example, population growth is 'profitable'; the contribution of each generation to its national income is such that the value of the goods produced is significantly greater than that of the goods consumed. And that is in spite of the fact that working life does not begin until 16 and the pension age is ear-

lier than in many other countries; average post-working life is 25 years for women (from 55) and 17 for men (from 60). That is what it means to create favourable conditions promoting a rapid increase of labour productivity and higher average expectation of life.

But when we look back! In Czarist Russia at the end of the nineteenth century the average expectation of life was 32, less than half the present, and working life naturally could not be the same as today, i.e. 41 years for men and 36 for women. If we also take the productivity of labour of those days into account, which was much lower than now, a surplus of wealth produced over what was consumed was achieved only through savage exploitation. And for all that it was meagre compared with today, not to mention that it was unjustly distributed.

That is now the distant past for us in the USSR, but for many developing countries it is the very real present. The average life of the Bantus, for example, is 35 years. Or take the Indians. How long ago was it that the average expectation of life in India scarcely exceeded 30? Now it has passed 45.

A purely quantitative approach, isolated from the qualitative changes in our world, is a very dubious basis for far-reaching forecasts. But that kind of abstract extrapolation, quite removed from reality, is vulnerable to criticism at both extremes, that of infinite pessimism and that of unrestrained optimism.

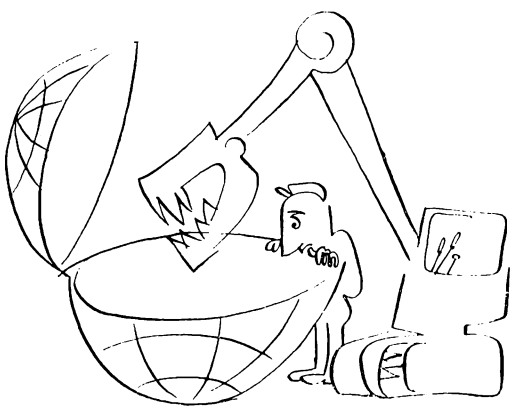
The complex world of living people and social relations is not so simple to describe by mathematical formulae and curves, however seductive their stringency.

That being so, do the difficulties of 'defining by number' really reduce the significance of the exponential law to naught for characterizing the rate of scientific progress? Not at all!

It is no good exaggerating the purely quantitative approach, of course, but it does enable us to see many of the distinctive features of scientific and technical progress at its present stage, when quantitative changes have begun to change into qualitative ones.

At its beginning an exponential curve remains nearly horizontal for quite a long time and is slow, as it were, to rise; then, it begins to rise more and more steeply and sweeps upward like the flight path of an aircraft taking off.

Isn't that how the path of scientific and technical progress goes? Humanity slogged its way on foot for a long time before it could saddle and harness horses; then, having changed over to more powerful and rapid forms of transport like trains and motor cars, it soon after sprouted wings and took off from the earth's surface. But if today's movement forward is comparable with flight, ever steeper and more headlong, may it not have its own 'ceiling' like aircraft?



But when it is a matter of the fruits of the tree of knowledge, of new discoveries and their application in the name of man and for the good of humanity, it is unlikely—rather, the more the merrier. Nevertheless, talk about a 'ceiling' is justified.

'There is one important material factor that limits the scientific and technical development of society in the end,' we read in Prof. I.S. Shklovsky's *The Universe, Life and Thought*. 'The resources of nature and energy required for it are not inexhaustible.' Let us suppose, he adds, that production of energy expands at a rate of 0.33 per cent per annum, which is ten times slower than at present. Its total, even at such a slow rate, would be doubled in 100 years, and would have increased 1024 times in 1000 years and a million times in 2500 years.

Such consumption could not be satisfied by harnessing the solar energy falling on earth (coal, oil, and gas would have been exhausted in the centuries immediately ahead). Are there any other possibilities?

Let us be optimists, says Prof. Shklovsky, and take it that humanity masters new sources of energy and learns to control the thermonuclear reaction. Suppose, too, that people learn to burn ordinary hydrogen in thermonuclear 'furnaces' as well as heavy hydrogen. To obtain it we would have to utilize the water of the world's oceans (or rather, part of it, say a tenth; it would hardly do to dry the world up more than that). But these vast (at first glance inexhaustible) reserves of raw material would, alas, be exhausted in several thousand years.

Prof. Shklovsky poses an interesting question: what grounds, in fact, have we for suggesting that the progress of humanity is inseparably linked with growth of the productive forces and that it must have any mar-

ked tempo in the future? May it not be that development will take a path of qualitative change only?

Social progress, he says, is unimaginable without development of the productive forces, both quantitatively and qualitatively, and in his view stopping of their growth would lead inevitably to the death of society.

So a quantitative analysis of today's trends, and yesterday's, projected into the distant tomorrow, is useful, if only because it warns us in good time that the society of earth dwellers will sooner or later need to reduce the tempo of its growth and development, at least as regards several indices.

Mankind, given wings by science and technology, must alter its flight path, which has been getting steeper and steeper, in good time and smoothly for a gentler one, so as not to be like Icarus.

But hold on!

Is it worth talking about a 'ceiling' in the age of space flight, in which this term is meaningful as regards aircraft but meaningless as regards rockets?

For hasn't a window onto the universe been opened to man? Won't he find living space, materials, and energy in plenty there?

Of course he will; but the settling of Mars, Venus, and other planets, the reorganization of the solar system into a comfortable habitation for man, capable of accommodating millions of settlers from Earth, as the New World once received European emigrants, is such an immense task that it will certainly take a long time to solve, perhaps centuries, if not millenia.

But has mankind so much time in reserve?

Let us take energy. If present tempos of development (doubling every 20 years) are maintained in the future, the consequences over some two or three centuries could raise most serious problems in a very sharp



form (disturbance of the earth's heat balance, and so on). It is not excluded that powerful energy systems will have to be extended beyond the confines of earth. But preparation for such an 'expansion to heaven' will have to be made by timely and intensive development of research in the field of space flight; and it is a very good thing that it has already begun in our time.

Prof. Shklovsky suggests that Jupiter and the other big planets, which consist mainly of hydrogen, could prove practically inexhaustible sources of nuclear fuel. But in order to exploit them progress in astronautics would not be enough; new advances would also be required in mastering controlled thermonuclear reactions.

In short, quantitative analysis of expected needs and possibilities is not simply useful but necessary, since it is out of the question, without it, to determine the most important and most promising trends in scientific and technical progress in good time.

But it may be objected that it is too hypothetical a forecast, if not sheer speculation, looking far into the future. It does not take into account revolutionary new discoveries and inventions that no one is able to foresee and that would qualitatively alter mankind's opportunities, making them more immense than they seem to present-day prophets. So is it worth getting steamed up if we people on earth have whole centuries in reserve?

'But, whether the exhaustion of supply will occur in a hundred or even a thousand years have we not some responsibility to our descendants living on earth at that time?' Dr. Donald H. Menzel, the American astrophysicist, pointedly asks in his book *Our Sun*. 'The exhaustion of fossil fuels—if not prepared for—would be a world catastrophe. The problem is great. Perhaps we shall require hundreds of years for its complete solution. It is not too soon to make a beginning.'

What does the reader think? A few other considerations would probably help you to answer.

The discoveries and inventions on which we always base our hopes when we come up against difficulties of one sort or another are not manna from heaven. For the tree of knowledge to bear fruit it is necessary to nurse it carefully and continuously, earmarking more and more new, and considerable, funds, and drawing in more and more gardeners, without whom its flowering is unthinkable. But, judging by the growth curve, here too, in the sphere of intellectual resources, in the development of the productive forces of science and technology, and in their financing, society may encounter a lot of problems. And not in some far distant future, but right now, in the next decade or so.

The different indices of scientific and technical progress are represented by various exponential curves.

Some are steeper than others, and the divergence increases rapidly with the years. Let us look at a few examples.

Science and its 'service sphere' are reinforced with personnel faster than industry, agriculture, or the health service. The tempo of population growth is also much lower. If this trend continued into the near future, it could turn out that our grandchildren and great-grandchildren, from the youngest to the oldest, would have to become scientists! That means that it is already time to be turning our minds to the problem of personnel for science and thinking about improving the system of general and specialized education, about a single-minded search for talent, about discovering still unutilized intellectual reserves in the human brain, not to mention already existing possibilities of raising the organization of science and the productivity of scientists' work to a still higher level, so as to counterbalance the quantitative limitations with qualitative improvements.

Expenditure on science and technology also cannot go on indefinitely exceeding outlay on all the other spheres of human activity. Otherwise there will be no funds for other purposes. But the limiting of appropriations will pose even sharper problems of choice. The fields of research are numerous and each of them has its own perspectives, but there are not enough capital resources for them all. How can the money best be apportioned? What should get priority? What should be sacrificed?

Now do you understand why it is already urgent to sort out what is important and what secondary in such a complex problem as scientific and technical progress? Which of its trends deserve the most attention, and which the least?

Quantitative analysis of the situation today helps

us to understand the special features distinguishing the present age from the past. Humanity has reached a critical stage; it stands on the eve of the period when the growth curves leading to the absurd can no longer follow the former mathematical law, exponential or otherwise. They must be changed for what are called logistic curves, which describe a logically assumed situation that does not entail ridiculous consequences. And the future of society depends on how correctly we succeed in determining the wisest line of development so that we can hold unswervingly to the planned course. For the future is laid down today!

Far-sighted control of all the processes of scientific and technical progress, enabling us to avoid disproportions between its various facets and to prevent all the outlay being wasted, has clearly acquired immense importance in the conditions now obtaining.

We Soviet people live in the first society in history to begin to implement nation-wide planning, both social-economic and scientific-technical. And we are not frightened by the 'mystique of the exponential', or the 'demonism of science and technology' that instil fatalistic horror in the souls of prophets who do not believe in the possibility of pitting reason against the elements.

No, the hopeless pessimism inspired by the uncontrollability of social processes under capitalism, with its free enterprise ('every man for himself') and its market forces, is not for us. The opposite extreme, too, is not for us, that of the happy-go-lucky optimism that prevents one from seeing the problems of the present and the future, and is tuned to an easy-going key dulling the sense of responsibility for decisions taken.

In his reminiscences of Karl Marx Paul Lafargue cited Marx's idea that science only achieves perfection when it succeeds in employing mathematics. Now,

when the management of society is being put on a strictly scientific basis, ability to compute is acquiring special significance. A quantitative approach—combined, of course, with a qualitative one in which the general formulae of the algebra of political economy are combined with the concrete data of social arithmetic—helps us to see problems and to analyse and resolve them.

In our day, when the transforming activity of man has taken on a truly gigantic scale, miscalculations in plotting its direction are fraught with serious consequences. Pebbles carelessly dislodged by walkers in the mountains can cause a veritable avalanche that is then incomparably more difficult to stop than to avert.

What are the roads and landmarks of scientific and technical progress? Can main and secondary directions be delineated? Is it possible to plot a general line, the trunk road to the future?

Our Present Age. The Thousand and First Revolution?

'The nineteenth century is often called the age of steam and electricity,' N.N. Semenov, Nobel Prize winner, has written. 'But what are we to call the twentieth century? The age of atomic energy? Or the age of the mastery of the air and outer space? Or the age of polymers? Or the age of radio, television, and electronics? Or the age of cybernetics and computers? Or the age of the mechanization of agriculture and application of chemistry to farming? Or the age of new medicines and prolongation of human life? And so on and so forth?'

The English novelist Aldous Huxley wrote (in the 1946 foreword to his novel *Brave New World*) 'the release of atomic energy marks a great revolution in human history, but not (unless we blow ourselves to bits and so put an end to history) the final and most searching revolution. This really revolutionary revolution is to be achieved, not in the external world, but in the souls and flesh of human beings.'

Many people consider that the future belongs to molecular biology, which has begun to flourish as

physics never did. But physics? Surely it hasn't said its last word?

'We are on the eve of a new revolution that will lead to a revision of our ideas and conceptions no less than that caused half a century ago by the theories of relativity and quantum mechanics,' I.E. Tamm, Nobel Prize winner, has said of the perspectives of research into the physics of elementary particles.

The French Nobel Prize winner, Louis de Broglie, suggests that we, the contemporaries of the new 'wonder of the world' embodied in the quantum generator, have still not fully appreciated this latest word in physics.

The laser has a great future, he says. It is difficult to predict just where and how it will be applied, but it is a whole technical epoch. But why the laser in particular? Why not, for example, transistors, or other semiconductor mini-instruments?

'The discovery of the semiconductor properties of ultra-pure and perfect crystals brought about a new revolution in radio engineering,' N.N. Semenov writes.

'The world is now undergoing a revolution in three aspects of technology: power, materials, and information,' Dr. George L. Haller, of the U.S. General Electric Co., wrote in *Automation* in 1964. 'All three are important, but the third, the Information Revolution, is having the greatest impact on our lives today.'

Prof. A. A. Dorodnitsyn, Member of the USSR Academy of Sciences, calls the electronic computer the foundation of a real technical revolution in means of processing information.

The American economist R. Theobald said in 1964 that the application of cybernetics was already dis-

playing the fundamental features of a revolution in industry.

And so on, in the same vein.

How many of these revolutions are there? Is there one of them that could be called the most searching, the 'really revolutionary revolution'?

'It is beyond our knowledge to know whether the computer, nuclear power, and molecular biology are quantitatively or qualitatively more "revolutionary" than the telephone, electric power, and bacteriology,' says the report to the President of the United States of the National Commission on Technology, Automation, and Economic Progress (1966).

N.B. Not simply 'we do not know' or 'still do not know', but 'it is beyond our knowledge to know'. Is it really and truly 'beyond our knowledge to know'? Is it possibly not generally worth while looking for quantitative and qualitative criteria of scientific and technical progress?

The many investigations made in the USSR and other countries provide an unambiguous answer.

But the problem is not an easy one.

G. I. Karkhin, for example, writes in his book *The Links of Present and Future in the Economy (The Scientific and Technical Revolution and Management)* that evaluation of the changes now taking place, the greatest in world history, and of their possible consequences, 'is complicated by the fact that the scientific and technical revolution is still far from its zenith. Much is still obscured by inertial fluxes of traditional events and connections. Hence also the differences in point of view.'

Karkhin distinguishes three approaches to the problem. The *first* is to seek out and record the separate features of scientific, technical, and economic progress, and all its conceivable indices (even secondary ones

that only characterize the external aspects of this complex phenomenon) that enable us to give a strict mathematical description of its state and perspectives.

The 'hunt for figures', and the collection and sorting out of statistical data of every possible kind, are an inevitable historical stage, of course. Collection precedes classification, and classification generalization.

As all the varied statistics are sorted out and systematized, attempts are made to distinguish their basic, determinant components, which include, for example, power, materials, and information.

But, as Karkhin notes, this approach does not really answer the questions that inevitably arise; whether, for example, such innovations as nuclear energy are qualitatively and quantitatively more 'revolutionizing' factors in industry in this century than the telephone, electricity, and bacteriology were in the last?

In fact, revolutions in the separate fields of science and technology, 'minor revolutions', occurred many times in the past. We find them in almost every historical epoch. The 'major revolutions' are quite something else, radical changes in every, or almost every, sphere of human activity, and above all in the means of production. They happen much less often. The industrial revolution of the eighteenth and nineteenth centuries was such a 'major revolution'.

There was no question of the present scientific and technical revolution until very recently, although the first seven decades of the twentieth century were rich in discoveries and inventions that entailed improvements of one sort or another in separate fields (power, materials, information, etc.). Do you want examples?

Take the revolution in science at the turn of the century, in connection with the discovery of X-rays, radioactivity, and the electron.

Or let us recall the seven-league strides of transport, both land and water; the headlong spurt of aviation, first piston engines, then jet aircraft, and now space flight; the development of power engineering, electrical engineering, electronics, communications, etc., etc. And didn't the invention and introduction of radio and television revolutionize techniques of communication?

And then there is the universal scientific and technical revolution affecting the whole life of society, above all its economic life, that people have only talked about since the second half of the century began. Karkhin, dating the beginning of this 'major revolution' from the end of the Fifties, concludes that, as a consequence, there are now other criteria of the qualitative shifts caused by it. What are they? Do we need to look for more general synthetic indices?

The *second approach.* In the second half of the Sixties attempts were being made to single out the 'main revolutionizing factor'. One of the conclusions drawn was that the essence of the present scientific and technical revolution was reflected as in a mirror in the 'compression phenomenon' already familiar to us, i.e. in the reduction of the gap between an idea and its realization, between the birth of a discovery or invention and its application in practice.

The time has passed when the offspring of research and engineering thinking fell as it were into a lethargy for decades and even whole centuries, like Ilya Muromets in the Russian ballads, who sat without stirring for three and thirty years before he found an application for the mighty force slumbering inside him. Today discoveries mature to commercial application in industry in a matter of a decade; tomorrow the 'incubation period' will be even shorter.

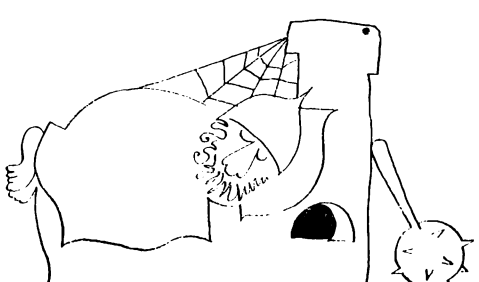
The time factor is a paramount one and plays an increasingly important role. It is quite impossible not to reckon with it in describing progress, and in particular, when evaluating the possibilities of a society and its relation to everything new, advanced, and promising.

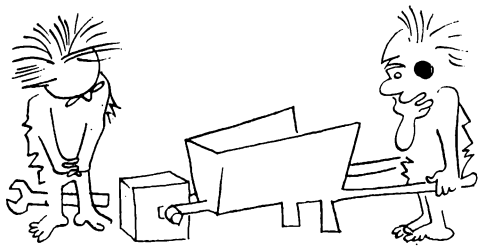
But if the practical application of discoveries and inventions is accelerating, once again, why? It must itself be the consequence of some cause, deeper-lying basis, or primary factor. But what? On this point, too, there are several views.

A.A. Zvorykin, in his booklet *The Scientific Revolution and Its Social Consequences*, asserts that 'the main thing about the modern scientific and technical revolution, its difference in principle, is the change in the relationship between science and technology. Whereas science used to approach nature mainly through the doors of technology, now it often approaches it directly, by-passing technology, and only reverting to the latter.'

Karkhin disputes this view, considering that it is one-sided (biased toward science) and does not reflect the essence of the changes in the productive sphere.

And it should be noted that this question of how the



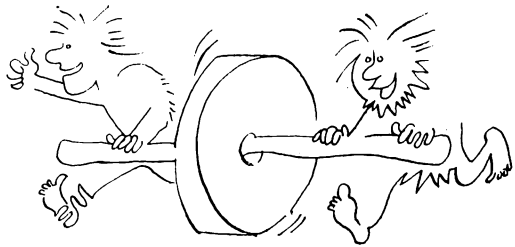


inter-relations between science, technology, and industry are changing is being heatedly discussed in the Soviet press.

Touching on it in his book *The Sociology of Science* Dr. G.N. Volkov protests against oversimplification when the matter is presented, as it sometimes is, as one of science being solely concerned with obediently fulfilling the demands put on it by industry. What about Lobachevsky's geometry? Or the theory of relativity? Or quantum mechanics? Did they develop through the solution of concrete tasks posed by technology? Of course not. But all these scientific advances will be sure to give a new impetus to technical progress (if they haven't already done so).

The development of science is not solely stimulated by the technical requirements and needs of industry. It also has its own driving forces. A new inference can be deduced from previous generalizations. In fact that is the way non-Euclidean geometry arose, for example, a typical example of fundamental research (so-called in distinction from applied research dictated by technical requirements).

This 'self-propulsion' of science, brought about by the inner logic of its development, also finds expression in the tendency noted by Engels in his *Outline*



of a Critique of Political Economy: 'Science increases at least as fast as population; the latter increases in proportion to the size of the previous generation, and science advances in proportion to the size of the body of knowledge passed down to it by the previous generation. . . .'

But purely theoretical, inquiring work very often has a practical purpose or direct economic benefit.

It is not without reason that we say that science is becoming a direct productive force. 'Science is now in advance of technical progress and leading it,' says Prof. B.M. Kedrov, prominent Soviet philosopher, Member of the USSR Academy of Sciences, and Director of its Institute of the History of Science and Technology.

So is it somewhere here, perhaps, behind this qualitative leap, behind the advance of science from the rearguard of progress to the vanguard, that the main revolutionizing factor of the present revolution lies? Perhaps the mainspring of social progress that we are seeking is concealed in the mechanism of the self-movement of science?

There is a view that the main factor in the present revolution in production and other spheres of social life must be sought in the driving forces of the deve-

lopment of science, in the sources of its revolutionary leaps. Science, it is said, has its own established concepts and methods and its own tools. But sooner or later they become powerless to explain the new facts accumulated by investigators, and come into conflict with them. 'Scientific anomalies' arise that are resolved by rethinking traditional opinions, by a raising of concepts to a higher level, which, with the economic application of scientific advances, itself leads to far-reaching economic transformations.

Criticizing this approach Karkhin argues his disagreement as follows. Science, even when it has become a direct force of production, does not itself directly produce material values, and in the final analysis its position and development are determined on the contrary by the needs of society.

Perhaps the famous 'main factor' is to be sought then in the advances of engineering and technology? After all they have the closest links with production. That is what H.R. Bowen, chairman of the U.S. National Commission on Technology, Automation, and Economic Progress, thought. But in disclosing the predominant factor underlying current social change he listed, alongside the automation of machine tools and nuclear power, the discovery of new methods of heart surgery and the teaching of foreign languages by electronic machines, and the introduction of self-service in retail trade, and frozen foods, and air-conditioning, and so on and so forth. But then, what is the predominant factor?

Others suggest that the most important leap forward in the development of the technical means of production is the transition to automation and the utilization of atomic energy.

But in the view of others still, 'the development of one definite field of engineering has put its stamp

on the scientific and technical revolution taking place in our time, and that is electronics'. The French physicist Pierre Auger calls our age laconically and unambiguously 'the age of electronics'.

But we are already familiar with such sobriquets (the 'atomic age', 'the space age', and so on and so forth).

The *third approach* can be called the complex approach.

In 1964 eminent scientists, engineers, businessmen, and writers, mainly American, published a manifesto on the 'Triple Revolution'. Their programme started from the premise that our age was characterized by three revolutions at once—the cybernetic (the spread of automation in industry), the military (missiles and thermonuclear weapons), and social-juridical (the American Negroes' struggle for civil rights).

The manifesto recognized that the mass movement of Negroes in the USA against segregation was an expression of the world movement for the establishment of just social and political regimes; that existing weapons of mass destruction made war unthinkable and useless for settling international conflicts; that automation did not blend with the capitalist system of distributing material values. Nevertheless, its authors trusted that automation had the power of itself to reorganize the social and economic structure of the bourgeois system so that there was no need to fight to change it. The present revolution, they said, was leading from a society of scarcity to one of abundance. In order to foster this metamorphosis, they suggested extending help to the unemployed (as if that would free them from scarcity and bring abundance!), introduce state regulation of scientific and technical progress (as if it were possible in the conditions of private enterprise!), and so on.

The main weakness of the manifesto, of course, was not the utopian character of its programme but the absence of a real analysis bringing out the essence of the present scientific and technical revolution.

In 1970 the Institute of the History of Science and Technology (USSR Academy of Sciences) published a study by a group of its researchers entitled *The Contemporary Scientific and Technical Revolution.* The theme was treated from every angle and the most varied points of view were expressed and discussed. Naturally there were many because the phenomenon is very complex. The authors concluded that 'B. M. Kedrov (whom we mentioned above—*L.B.*) has most clearly disclosed the essence of the contemporary and technical revolution.... Whereas the essence of the technical revolution of the second half of the eighteenth century and beginning of the nineteenth lay in the creation of working machines, i.e. in the replacement of the worker's hands by a mechanism, the essence of the current scientific and technical revolution is the replacement of the logical functions of the producer by machines.'

Well, if we try to express that in a single word, what do we get? The best, it would seem, is 'automation'. But of course that is dangerously laconic; questions about its meaning and where it is going are inevitable and unavoidable.

Another member of the USSR Academy of Sciences, Prof. V. M. Glushkov, concludes that the scientific and technical revolution 'has not only inscribed the automation of physical labour on its banner, but also the automation of mental work, the full automation of industry, and unlimited multiplication not only of the information resources and intellectual capacity of humanity but also of its power potential.'

But perhaps he is grinding his professional axe? For

Prof. Glushkov is an eminent authority on the theory of automatic machines, and director of the world-famous Institute of Cybernetics of the Ukrainian Academy of Sciences in Kiev. How would the representatives of another branch of knowledge view the situation?

Let us take the view of a physicist Prof. E.L. Feinberg, Corresponding Member of the USSR Academy of Sciences. 'It is sometimes said that something new happened with cybernetics. In that simple form, without quantitative analysis, this thesis is easily refuted.... Clocks, especially the cuckoo clock, and the complicated fireworks of the days of the Empress Anna were all cybernetic-like devices.'

Prof. Feinberg stresses that the quantitative laws of the development of science are the same on average over many centuries for the whole world, and that scientific discoveries astounded their contemporaries 100, 200, and 450 years ago. 'It means,' he concludes, 'that we are not the first who, worshipping science, praise its (regular) "prodigious revolution". . . . People are right when, astounded that more has happened before their eyes than in all past history, they give the palm to the science of their own time. But they are wrong when they think that this is something exceptional, characteristic only of their own time.'

He suggests that science does not change of itself; the laws of its internal development have remained the same as they were 400 years ago. What is unusual and new is something else, its special position in present-day society. 'In the first place,' he says, 'science (including the advanced technology of any period linked directly with the development of science) has now drawn the greater part of society into the sphere of its direct activity. . . .

'Secondly, the period elapsing between an "ab-

stract" scientific discovery and its application in everyday practice has become much shorter. . . .

'Instead of the first criterion, or alongside it, we can pose the problem as follows: the proportion of the national income expended on scientific and technical research is not negligible. Or putting it differently, the fraction of social labour performed by devices of a cybernetic type is not small, and in that sense the people who see the essence of the modern stage in the introduction of cybernetics are right. Thanks to these qualitative changes science has become one of the main elements in the productive forces.

'It is scarcely worth arguing about the exact choice of index. Two main factors would seem to be important: first, the mass scale of science, and second the speed of the passage from "abstract" science to practice.'

So, are we brought back again to 'definition by number'?

But, however debatable Prof. Feinberg's penchant for quantitative criteria, he is quite justified in warning against subjective judgments born of the enthusiasm of people for the discoveries and inventions of their own time.

The Measure of All Things

A false tale of how, long ago, Ossa and Pelion were piled on Olympus has been preserved for us down the ages. But the pyramids of the Nile still rear their proud pinnacles to the golden Pleiades. . .

Thus a nameless Greek poet extolled the amazing structures that were unanimously counted as the Seven Wonders of the World.

Whatever we think of those who lavished such care on the preservation of their future mummies, it is impossible not to be impressed by the scale of the concepts. The Great Pyramid of Cheops, for example, erected more than 4700 years ago, in the Bronze Age, remained the highest building in the world until the end of the nineteenth century (originally it was 147 metres high, and then, after the collapse of the top, 137 metres). Each side of its square base was 233 metres long.

This most vast of all sepulchres was built up from 2 300 000 blocks of limestone, each weighing more than two tons, and so carefully dressed that they fit each other exactly. It is said that you cannot even insert the blade of a penknife between them, so closely are they laid.

Thirty years it took to build that tomb. The number of slaves working at any one time on the building site was as high as 100 000.

Even in our day sightseers gaze with reverent, nearly religious awe on the stone mass of this seemingly superhuman creation, before which there seems nothing left for people to do but to realize their utter insignificance and the whole transience of their existence.

It is certainly perennial and indestructible, that feeling of awe and wonder before everything prodigious and out of the ordinary. And there is no doubt that this human quality, which is very human indeed, is laudable—but doesn't it remind you now and then of a magnifying glass, marred by an aberration of some sort? Doesn't it prevent reality being reflected in the mirror of reason and distort the true scale of values?

But what has that to do with scientific and technical progress? Or with the world of ideas and things that objectively exist, as the philosophers say, independently of our subjective impressions?

'Progress' means 'movement', eternal movement, an amazing *perpetuum mobile* in which something prodigious and out of the ordinary is born in every age: today something that did not exist yesterday, and tomorrow something that does not exist today.

But the something that will come tomorrow still does not seem ponderable, tangible, and visible today, like the pyramids. It is still swarming as ideas in the heads of scientists and engineers; at best it lies on their desks in heaps of paper covered with figures and drawings. It is still simply 'hoo-ha', 'a sound intangible to the senses' as Gogol's Chichikov phrased it when making clear to Sobakevich the whole immateriality of dead souls. Are you sure that some of the newborn ideas won't prove stillborn, that there are no hare-brained schemes among these projects, however deserving of astonishment and admiration?

Imagine that you must accept or reject a project

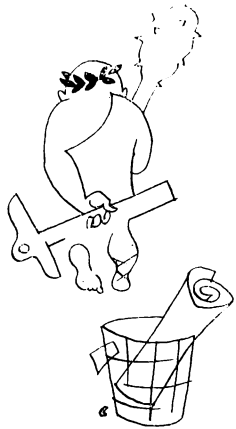
like this—someone has proposed a design to you 'for the shaping of (Mount Athos) into the statue of a man', to carve 'the noblest and most durable statue in the world', in whose left hand would be 'a very spacious fortified city' with ten thousand inhabitants, and 'in his right a bowl to receive the water of all the streams which are in that mountain, so that it may pour from the bowl into the sea'. It would be really wonderful, wouldn't it? Truly the 'eighth' wonder of the world. But there is a chance, of course, that you would reply with a question: 'Whatever for?'

Alexander the Great reacted rather differently.

Here is the story as it has come down to us from the classical writers Plutarch and Vitruvius.

The project described above is said to have come from the Macedonian architect Dinocrates (or Stasicratus, as Plutarch called him). It was not easy to push one's way into an audience with the ruler of the greatest power in the ancient world, and even more difficult to capture his attention, let alone his approval, for Alexander was surrounded by many of Stasicratus's colleagues, a host of scholars and engineers. Knowing that, the landless fellow-countryman of the conqueror of the great expanses stretching from the Danube to the Indus 'anointed his body with oil, set a chaplet of poplar leaves on his head, draped his left shoulder with a lion's skin, and holding a club in his right hand (an attribute of Heracles, whom Alexander did the honour of considering one of his ancestors—*L.B.*) stalked forth to a place in front of the tribunal where the king was dispensing justice.'

His strange appearance, says Vitruvius, 'made the people turn round, and this led Alexander to look at him. In astonishment he gave orders to make way for him to draw near and asked who he was.' Stasicratus spoke eloquently, and in all likelihood convin-



cingly. Having heard him out, Alexander 'was delighted with the idea', but before he committed himself he wanted to know 'whether there were any fields in the neighbourhood that could maintain the city in corn'. Stasicratus replied that the problem of food supply could only be resolved by importing grain from overseas.

Alexander rejected the design. As a pupil of Aristotle he gave an answer worthy of his teacher. 'Anyone who should found a city in that spot would be censured for bad judgment. For as a newborn babe cannot be nourished without the nurse's milk, nor conducted to the approaches that lead to growth in life, so a city cannot thrive without fields and the fruits thereof pouring into its walls, nor maintain its population without a supply of it.' It was almost unheard of, but the enlightened ruler, unlike Cheops, thought about others, about simple mortals, as well as about himself and his 'godhood'. His dreams of immortality were linked, not with a necropolis, a city of the dead,

but with a city for the living, and with its prosperity.

The legend resembles a parable. It is directly didactic. An intoxicating feeling of awe and admiration, very human, perhaps too human in its subjectivity, must go hand in hand with sober, critical, common sense.

One can understand Stasicratus, who apparently did not possess the happy combination of youthful enthusiasm and adult wisdom. But to understand Alexander, and even more to condone him—for wasn't he right, this man, who disposed of incredible possibilities, when, having weighed them against the needs, he answered 'No'? Nevertheless, Cheops, too, before deciding the best project for his tomb, must have weighed up the possibilities and requirements. And he was also certainly guided by considerations of expediency. Only he understood them in his own way.

Today, of course, that criterion of expediency—and it cannot be avoided in evaluating any idea or creative work, great or small, whether scientific or not—is understood differently. The problem of expediency is an eternal theme of philosophical discussion, but the whole point is that almost everyone and not just philosophers comes up against it at nearly every step. And in every case everyone must decide it for himself. The whole question is—how?

In January 1960 the building of the Sadd al-Aali, the High Nile Dam, began in Egypt, near Aswan, 111 metres high and almost a kilometre thick at the base. The volume of the earth alone to be shifted in making this new 'man-made mountain' was that of 17 Great Pyramids. In May 1964 the Nile was dammed.

The foreign reporters who were there looked, as always, for impressive figures and pictures. It was a joke to say '17 pyramids! and all done in four years

and four months'. Sadd al-Aali came to be translated into other languages not simply as the High Nile Dam, but also as the 'eighth wonder of the world'.

'Do you know what the main thing is about this dam?' Dr. N.A. Malyshev, who was responsible for drawing up its plans, asked the journalists besieging him. 'It is that the whole nation gains from it, all the 30 million inhabitants of Egypt!'

What did he mean?

Behind the dam, an artificial reservoir, one of the biggest on our planet, had been formed, which was giving the parched land life-giving moisture that used to flow into the Mediterranean Sea without benefit to crops. Year-round irrigation of the fields was enabling two or three harvests to be taken from them. And at the same time the Sadd al-Aali was saving the river below it from the floods that used to cause 30 million Egyptian pounds of damage to the country every year.

The Nile is harnessed now and working like a powerful team of horses. In 1970 the power of the Aswan Dam exceeded two million kilowatts and the length of the high-voltage transmission lines leading from it 1500 kilometres. And there in the desert, where the steel 'palms' of pylons have sprouted, oases of industry are rising.

But what about the seventeen pyramids in the dam? That's a lot of pyramid. But twenty would be even more! And why twenty? Why not twenty-seven? Or simply seven?

Exact calculations made at the Gidroproekt Institute in Moscow for Dr. Malyshev gave precisely seventeen. Only with that many pyramids could they successfully dam the Nile in the best possible way.

The first scheme for the Aswan power station, it should be noted, was drawn up by a famous British

firm of civil engineers. But an international commission accepted the work of the Soviet engineers as best.

'It has confirmed the reputation of the Soviet school of hydraulic engineering,' declared Ivan Kulev, Vice-chairman of the State Committee of the USSR Council of Ministers for Foreign Economic Relations. 'The reaching of agreement began with a critical review of the project, in which the biggest civil engineering firms in the world took part. The Soviet engineers led by Dr. Malyshev introduced cardinal changes making construction cheaper and simpler. At the same time their changes made it possible to cut the construction time originally estimated by two years.'

Other specialists could learn from that approach to things.

For the grandiose dimensions and overwhelming massiveness of certain machines and structures—hundreds of thousands of tons of steel structures, millions of cubic metres of concrete, huge machine tools and machines—exert a very hypnotic effect not only on us, the uninitiated, but also on professional scientists and engineers who are far from tyros in their fields. But isn't effectiveness better than effect?

Let's look again at Cheops' pyramid. Yes, there is a real wonder of the art of engineering. But, pardon the expression, what the hell's it for?

Scholars, who are not easy to accommodate to the idea that an undertaking (especially one so vast) is senseless, have hazarded guesses—perhaps it is not just a supertomb? Suppose we have here an imperishable testament to posterity, some kind of silent 'stone letter' in which information on the mathematical and astronomical discoveries of our ancestors is coded in the dimensions, measurements, angles, proportions, forms, and arrangement of the tomb? Piazzi Smith, the Astronomer Royal of Scotland, for example,



spent two whole years investigating the Great Pyramid in this way in an effort to 'crack the code' and in publishing his findings. But alas, neither he, nor anyone else, has succeeded in disproving the commonly held idea that we have nothing more here than a stupendous memorial to the 'god-like' sovereign of mortals.

Nevertheless let us be just. Before us is the embodiment of the genius of a people who have disappeared from the face of the earth, materialized knowledge, technical and scientific, embodied in 'man-made mountains'.

For work is nothing more than the embodiment of an idea. But is it justified when the idea of a vainglorious despot drains the forces of a whole nation for decades for his own personal, egoistic interests? Thousands of people perished from back-breaking toil and frequent accidents, and thousands of unfortunates were pitilessly slaughtered when the building was

completed, so that no one should know where the inner passages were that led to the sarcophagus and the treasures surrounding it. Thousands of names were buried in oblivion so that one single name should never be effaced from peoples' memories. It is stamped everywhere possible, even on the blocks of stone from which the tomb is built—Cheops, Cheops, Cheops. The real builders have vanished in Lethe. Everything was done to kill the living and perpetuate the dead. The corpse overshadowed their toil.

But time long ago washed away the tears, sweat, and blood from the cold stones, and the pyramids 'still rear their proud pinnacles to the golden Pleiades'.

A truly staggering memorial to genius and evil-doing!

Hiroshima, converted into a cemetery, was also 'materialized thought', also the 'imprimatur' of a civilization that gives a certain idea of the level of scientific and technical progress in the country whose rulers created a gigantic sepulchre in an instant to show the world what they were capable of.

'Operationally, we must consider an invention not only with regard to what we can invent but also as to how the invention can be used and will be used in a human context,' Norbert Wiener recognized, as if giving to understand that the rosy spectacles of childishly direct (but also childishly naive) wonder and admiration are not really so harmless a joke when their magnifying glasses do not have a scale of human values engraved on them.

One can understand the impression produced by the explosion of the first atomic bomb on the testers. 'The scene inside the shelter was dramatic beyond words,' said Gen. Farrell, the deputy director of the Atomic Bomb Project, according to the U.S. War Department press release on the New Mexico test,

on 16 July 1945. '...It can safely be said that most of those present were praying ... If the shot were successful, it was a justification of the several years of intensive effort of tens of thousands of people...'

And now the project, which had cost two thousand million dollars, had come 'to the fullest fruition'. 'Dr. Kistiakowsky threw his arms around Dr. Oppenheimer and embraced him with shouts of glee.... All seemed to feel that they had been present at the birth of a new age—The Age of Atomic Energy—...there had been brought into being something big and something new that would prove to be immeasurably more important than the discovery of electricity or any of the other great discoveries which have so affected our existence.

'The effects could well be called unprecedented, magnificent, beautiful, stupendous and terrifying.'

One can understand the emotion of the scientists and military (as to the war, some had 'a feeling that no matter what else might happen, we now had the means to insure its speedy conclusion'; a war, let us add, that would have been quickly won without it). It is possible to understand—but to condone?!

'A blinding greenish flash, an explosion, consciousness was overwhelmed, and the next moment everything was burning. In an instant blazing clothes fell off people, arms, faces, and chests swelled, the red blisters broke and shreds of skin slipped to the ground. Deafened and burned people, out of their minds, bunched together in wailing, howling groups, and staggered blindly about, seeking to escape...' That is how the hell of Hiroshima stamped itself on the memory of witnesses.

In his book *Atoms and People*, the well-known American atomic physicist Ralph Lapp appraised the decision to use the bomb against Japan 'as one of the

greatest errors of judgment on the part of U.S. officials', and bitterly remarked that 'what is worse... some upper-crust scientists collaborated with the military in their unimaginative use of the bomb'.

Soon after Hiroshima and Nagasaki the world was shocked by Nuremburg, the epilogue to that even greater world tragedy in which more than 50 million people lost their lives in a few years, wiped out by the 'last word' in science and technology. A veritable war machine passed over them, while in the concentration camps worked 'death factories' where people were exterminated directly by industrial methods. There, too, 'scientific' experiments were carried out on living prisoners.

But what were the warriors of the 'Third Reich' and their bombs to today's Malbrucks? The 'global strategists' of the Pentagon operate with the concept of 'megadeath'—a unit for measuring mass extermination equal to one million dead.

Today's thermonuclear bombs are a thousand times more powerful than those that fell on Hiroshima and Nagasaki, leaving hundreds of thousands dead and maimed. That, too, is progress! An aspect of the notorious 'triple revolution'. And also something effective and effectual. Only it is a weapon—a weapon of mass destruction and annihilation—and not a tool of creation.

'The most important realization, and one which is not yet sufficiently widespread,' the British Marxist and scientist, Prof. J.D. Bernal, F.R.S., showed with facts and figures in his book *World Without War*, 'is that the benefits of using science for welfare are so great as to make entirely pointless all the disputes about which wars have been fought in the past and for which countries enter into defensive and offensive alliances. The wealth that could be available to us

now, through the application of the amount of science we already know, is far greater than anything that could be obtained from the conquest of the most fruitful territories or by winning the most exclusive controls of sources of raw materials, oil, or coal.'

For if the arms race were stopped, the atom bombs already stockpiled could be used for the good of humanity. In the Soviet Union, for example, many different experiments have been made with demobilized atoms.

An underground nuclear explosion leaves a wide cavity in the earth with fused walls and a narrow vent. After the level of underground radioactivity has decayed, gas or fluid can be stored there—a magnificent reservoir that can compete successfully with metal storage tanks. 'Let the atom be a worker not a soldier' is inscribed on the pediment of the Novo-Voronezh atomic power station.

The weapon is capable of halting all progress and any revolution, and has justified the gloomy prophecies of Bertrand Russell's allegory. If we are interested in the future of scientific and technical progress, it follows that we tacitly mean that it will continue its onward movement. So, tools, not weapons! And effectiveness, not effect. 'Everything in the name of man, everything for the good of man' is the slogan inscribed in the Programme of the Communist Party of the Soviet Union, and it applies automatically, it would seem, to every peaceful achievement of scientific and technical progress.

Imagine a tool that doesn't simply help you to work but itself does many very complicated operations for you. It would be just the thing, wouldn't it.

'Worse than the nightmare of Hiroshima!' What do you think is meant by that? Automation! It turns

out, as Norbert Wiener wrote in his book *Cybernetics*, that automation could really become an evil 'in a society like ours, avowedly based on buying and selling, in which all natural and human resources are regarded as the absolute property of the first businessman enterprising enough to exploit them. . . .'

In November 1960 the motor-car industry of France did not seem to be suffering a crisis, nevertheless Renault, a very forward-looking firm, decided on a partial lockout because the 'electronic brain' that kept track of its stocks and analysed the state of the market advised a cutting-back of production. The workers, indignant at being laid off, smashed the computer installed in Boulogne-Billancourt. But alas, that was not the right address for their anger; the automaton was only serving the interests of the management.

Their reaction was a throwback to the Luddites, the movement that arose at the beginning of the nineteenth century in England directed against 'machinery'. It took its name from the legendary King Ludd who first broke his machine, seeing in it a 'fiend' doing harm to people. The real 'Satan', capital, 'His Obscene Highness Capital', long remained invisible. But when the proletariat began to see things clearly, capital did everything it could in order to shift the blame onto somebody else.

'Gentlemen of the jury, no doubt the throat of this commercial traveller has been cut. But that is not my fault; it is the fault of the knife! Must we, because of such a temporary inconvenience, abolish the use of the knife?. . . Should you abolish the knife, you would hurl us back into the depths of barbarism.'

With those words Bill Sykes, Dickens' philosophical cut-throat who got into *Das Kapital*, seared the hearts of the jury. Marx employed this quotation from *Oliver Twist* in order to ridicule the bourgeois eco-

nomists who made a fetish of machinery. For them the creations of the human mind and human hands, alienated from people, acquired such an independence that they began to lead a separate existence with, as it were, their own destiny.

Discoveries and inventions, the products of scientific and technical thought, began to resemble the products of religious fantasy, which seem to the believer, as Marx said, to be 'independent shapes, endowed with lives of their own, and able to enter into relations with men and women.'

That sort of attitude proved to have great vitality; it is frequently met, though not always noticed, even today. And as a rule it involved passivity, in the form either of a fatalistic, pessimistic humility ('it doesn't matter what you do about it; what will be will be') or of an easy-going, optimistic light-heartedness ('let's hope everything will come right of itself').

Prof. J.B.S. Haldane had already dealt with this 'theme of fate' in his *Daedalus or Science and the Future* when he answered the question asked by the opponents of science: 'Has mankind released from the womb of matter a Demogorgon which is already beginning to turn against him and may at any moment hurl him into the bottomless void?' Now they talk about the coming 'Hiroshima of automation'.

But it all depends in whose hands the fruits of science, so hopeful, it would seem, and cultivated by the best intentioned gardeners, are concentrated in.

'For the capitalist automation is a social threat and its rejection an economic one,' wrote the progressive French economists Claude Vincent and W. Grossin in their study for the French Communist Party *L'enjeu de l'automatisation (The Stake in Automation)*. 'For the socialist countries automation should turn out



to be a powerful means of proving their economic superiority over capitalist systems.'

And according to the American publicist John Morris, automation and the other technological innovations that are rapidly penetrating the American economy are a curse for American workers and not a blessing, as they have become in the socialist countries.

Those are all copy-book maxims. But does that mean that we should greet every project for automation with cheers?

Here is what Prof. V.A. Trapeznikov, Member of the USSR Academy of Sciences and Director of the Academy's Institute of Automatic Systems and Telemechanics (Technical Cybernetics), says: 'The removal of some of the operators that govern production usually requires the introduction of complicated equipment, most of which can scarcely be justified. The substitution of automatic devices for operators is only advisable with the simplest algorithms of control,

in hydro-electric power stations, for example, and points on radio-relay communications. But even then the transition to the automatic undertaking should be based on strict economic estimates.'

Such an approach to the matter is blocked for certain specialists by the psychology of 'gadget worship', as Norbert Wiener called it. 'There is a cult of technique,' he lamented in an interview in *Literaturnaya gazeta* when in Moscow for an International Cybernetics Congress. 'People worship gadgets.' He expressed much the same idea in *God and Golem Inc.*

There is no argument about it but any machine surpasses man in something (a computer, for example, in speed of calculation). But that also applies to any tool (or weapon), however primitive, even a stone axe; the creator (or destroyer) who has it at his disposal proves more powerful than he who only has his bare hands. But is it worth imitating the cavemen who, dazzled by this magic force, prostrated themselves before a stick with a stone attached to it, spiritualizing the 'soulless creation', elevating that which easily dealt death but did not die above him even who created it, above themselves and all other mortals?

Is it worth asking what magic power 'magical' devices that acted by themselves, automatically, unlike the axe, would have exercised over the minds of our ancestors?

Let us recall that the first machine was born some 20 000 years ago. It was the trap or pitfall for catching animals. 'Blueprints' of its various versions can be seen in the Ice Age 'frescos' depicting hunting scenes. These rock paintings, so profusely 'shown' in the famous 'cave galleries', were used in shamanistic ceremonies resembling prayers for good fortune. Would they have elevated so demoniacally perfidious and

wonder-working a Mechanism to the heavens in their rituals if it had not, though so small and seemingly simple, possessed really supernatural power, capable of bringing down huge, powerful beasts like mammoths, bisons, and bears?

That is when the first 'gadget worshippers' appeared!

In the view of the German ethnographer, Julius Lips, author of *The Origin of Things*, 'the invention of the first animal trap was certainly of greater consequence to the history of mankind than the invention of the wheel. The application of the newly found motive powers in building animal traps had greater consequences than any other single invention in the technological history of mankind.'

Let us do justice with Herr Lips to the hunter's trap as possibly the oldest of the 'wonders of the world'. But let us give another 'trap' its deserts as well, a trap no less ancient, that was also born of human thought, and into which human thinking itself has been falling since time immemorial. We refer, of course, to the nearly religious, ecstatic amazement or adoration of every kind of 'wonder' of science and engineering, when the aura of the highest visionariness and contrivement surrounding them eclipses the figure of Man himself, of him by whom they were created and for whose sake they were created. You will recall the argument between Haldane and Bertrand Russell; however contentious their conclusions, they put their stress on the world of people (Daedalus, the symbol of creative genius, and Icarus, the image of all humanity given wings by science and technology) at a time when universal interest was rivetted, as it still is today, on the realm of ideas and things (wings personifying the fruit of the tree of knowledge).

'Man is the measure of all things,' the ancient sages proclaimed.

There would probably be no need to recall that if it weren't for the gadget worship that Norbert Wiener speaks about. For the invasion of life by machines creates problems as well as solving them.

In our day a mistake by the operator in charge of automatons, and giving them commands, is fraught with catastrophic consequences. Quick and proper responses to danger signals are required. But what would happen, if the flow of information from instruments overwhelmed him, if now and then he were dazed by all the signals—coloured lamps, illuminated displays, pointers and needles, dials and scales—and if the control panel abounded in switches of all kinds—knobs and buttons, knife switches, dials and wheels and pedals? Willy-nilly, he would wish he were hundred-eyed Argos or six-armed Shiva.

To help pilots, controllers, and operatives—in a word, everyone in charge of present-day machinery (at once good and terrifying)—engineering psychology has been developed. By studying the psychophysiological capabilities of man, it discloses his latent, still unutilized reserves. But the main thing is that it tries to adapt these, alas limited, capabilities to the mounting requirements of technology for faultless guidance by man.

Today, as more and more cars appear on the streets and roads, as the transport network becomes more intensive and complicated, as the numbers of huge factories increase and the scale of technological processes grows, the problems investigated by engineering psychology become more and more pressing and urgent. Neglect of them means an increase in industrial injuries, road casualties, and fatal accidents.

Making a fetish of scientific and technical advances leads on the one hand to exaggeration of their importance and to their all-too-hasty introduction, and

on the other hand to underestimation of its negative consequences. But is it just the indifference of the 'inculcators', a thousand times condemned, that prevents due regard for people and proper concern for nature? Or doesn't the much lauded, unregarding enthusiasm of the 'gadget worshippers', developing into a cult, have some effect?

'Marxism by no means attaches less significance to the advances of science and technology than technicism (which, incidentally, often decks itself out in Marxist clothing),' writes Prof. G.N. Volkov in his *The Sociology of Science*. 'While highly esteeming these achievements, the founders of Marxism at the same time never made them an absolute, never assigned them a self-sufficient role, never counterposed them to living human activity, but, on the contrary, looked on them as the products of productive labour and as tools of that labour.'

'Technology and science,' he says further, 'do not exist apart from human activity and, with it, constitute the productive forces of society. And it is the development of the productive forces in their whole totality that acts as the mainspring of social progress.'

Here we reach a kind of turning point. So far in our historical excursions and our attempts to understand the meaning of scientific and technical progress we have broadly followed the commonly accepted approach, as though science and technology were above all inventions and discoveries, ideas and their embodiment at any stage. Man, their creator and their user, remained, as it were, in the background. But it is man who is the central figure in all Marxist sociology; and only by focussing our attention on him and his labour can we better understand—not completely, of course, but catching or sensing—

the essence and perspectives of scientific and technical progress, in particular at its present stage, the scientific and technical revolution and its determining trend, automation.

But first we must consider certain basic concepts. What, to begin with, are the productive forces?

Half-a-century ago a discussion developed among Soviet economists that reached its pitch in 1928-9. According to one of our leading economists, Prof. A.I. Pashkov, Corresponding Member of the USSR Academy of Sciences, some of the participants treated the material character of social production in an incorrect way, equating the concepts 'material' and 'natural'. 'The productive forces of society were identified with the means of production, with technological equipment,' we read in his book *Lenin and the Development of Economics in the USSR*. 'The statement of the founders of scientific communism, that the main productive force of society was the workers themselves, the labouring men, was ignored.... The productive forces as a whole were eliminated from the subject matter of political economy.'

Let us re-open Prof. Volkov's book, which we quoted above. 'Our social sciences,' he says, 'have unfortunately paid little attention to studying the productive forces. For many years there was an "absolutizing" of productive relations (i.e. property relations) and overestimation of their importance; it was suggested that the socialist system of production of itself already assured us of superiority in economic competition with the capitalist world, and that productive relations played the major, decisive role in this competition and development of the productive forces a minor, wholly subsidiary, and dependent role. More attention is now being paid to the laws of the development of the productive forces and to problems of

the scientific and technical revolution, both in theory and in practice. But the fact is that the sphere of the productive forces has proved a no man's land. Political economy concentrates on productive relations while sociologists apparently have not got that far. But life urgently demands a thorough-going analysis of technological relations and the development of a Marxist sociological theory of the productive forces, in particular, a sociology of science.'

What is the role of science, and technology then, and their place in the system of productive forces?

The 'Perpetuum Mobile' of Progress

What was the first skyscraper? The question scarcely presents any difficulty. It was the Pharos lighthouse, built in 230 B.C. on a cliff on the island of Pharos near Alexandria. It reared upward for 170 metres. Its fame is preserved to this day in the French word for a lighthouse or the headlamps of a car *phare*, which we also use in Russian. But who built it?

That question has led many people up a blind alley. Why is it when we learn about a 'wonder of the world' or visit a temple of learning (science) or a palace of engineering, that we are all, for no reason at all, more interested by big buildings than by the men who made them? And for that matter those who acquaint us with the latest achievements of science and technology, the organizers of exhibitions of all kinds, strive to introduce us to a world of ideas and not to one of people.

But is it so very important, in truth, to satisfy someone's curiosity about the name of the author? Pythagoras long ago said that form beautifies a statue but what he does a man. H.G. Wells thought that the

history of mankind was mainly the history of ideas; but Karl Marx wrote in a manuscript of 1844 on private property and communism: 'the *entire so-called history of the world* is nothing but the begetting of man through human labour'. And Frederick Engels said in a letter to Lasalle that personality was not so much characterized by *what* it did as by *how* it did it.

Our interest in discoveries and inventions is quite natural. But they are all finished, end results, while it is the productive forces, the mainsprings of progress, that really concern us, and consequently, the deeds of people, and not just the results of the work performed, but above all the labour activity itself, from its conception to its completion.

Let us try out this new angle for looking at technique (for it is technique, or rather its degree of development, that serves as the most exact measure of the development of the productive forces). What does technique represent?

In his *Grundrisse der Kritik der Politischen Oekonomie* Karl Marx said that nature built no machines, no locomotives, railways, electric telegraphs, selfacting mules, etc. They were products of human industry, natural materials transformed into organs or instruments of man's will over nature or of his action on nature. They were 'organs of the human brain created by the human hand', he stressed, 'the power of knowledge objectified'. That definition places technique in a very close relationship with man and his activity, and also, incidentally, with nature. It helps us to understand the inter-relation between technique (the objectification of the power of knowledge) and science (potential technique). We can also apply the term 'potential technique' to work skills developed into automatic habits, labour experience, and ways and methods

of working. The Greek word *tekhne*, incidentally, meant 'knowhow', 'mastery', 'virtuosity'.

Tekhne is a word from the dead language in which Herodotus described how the 2 300 000 two-ton blocks that went into the Great Pyramid of Cheops were prepared.

The quarries were on the right bank of the Nile, not far from Memphis, the ancient capital of Egypt. Even grooves were hollowed out in the rock and deepened. Dry wooden wedges were driven into them and soaked with water. The wedges, swelling, transformed the grooves into cracks, but the massive blocks resisted a long time before they finally came away. The blocks were raised by hand from the bottom of the quarry by means of ropes of papyrus, and trimmed; then the long haul to the river bank began. There they were loaded onto rafts and ferried to the other bank, from which they were finally dragged on wooden sledges to the building site. And so it went on, for thirty long years.

Tekhne—the same word is heard in the well-known modern word, which sounds almost the same in all languages. Ages have passed but the concept lives. But how its sense has altered!

Explosives and machines—bulldozers, excavators, self-tipping lorries, mobile cranes, and self-discharging barges—are what enabled the vast volume of earth work on the Aswan Dam to be performed, equivalent to the building of at least ten Great Pyramids. (On the construction of the first section of the Nile complex alone more than 3000 Soviet machines and around 2000 Soviet engineers and technicians were employed.)

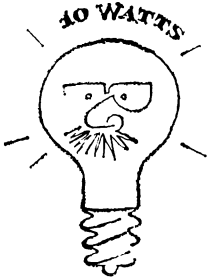
Against the background of his powerful auxiliaries —machines—man, disposing only of the strength of his own muscles, seems a rather puny creature (his strength averages about forty watts). When conti-

nuously involved in physical effort every day for eight hours a day (except Saturdays and Sundays, of course) he does work over a year the equivalent of around eighty kilowatt-hours, which is only a tenth of the electricity alone that he uses. And he uses other forms of energy as well.

Now, for the sake of comparison, let us consider the power supply of the Soviet Union in all its ramifications from giant power stations to small contact blades. Its potential is approximately two million megawatts, or the equivalent of the muscle power of 50 000 million people (the population of the USSR in 1973 was 250 million). Power drives machines, provides light, warms us, feeds us, clothes us, creates comfort, and multiplies our power over nature. It is not without reason that the power capacity of a state has become a measure of its national wealth.

But all these thousands of millions of horsepower imprisoned in the man-made muscles of these indefatigable sloggers were called into being and built by that same weak 'motor', the creator and discoverer of all national wealth, *Homo sapiens*, Thinking Man.

Now compare these figures—forty watts and ten watts. The second—it looks quite tiny, doesn't it?—is the power of the human brain. But we must imme-



diately make a reservation; that 'mechanistic' comparison implies nothing derogatory for the crowning glory of biological evolution. As a matter of fact, the brain case of man, which is of modest volume, around a litre and a half or two litres, contains a real masterpiece of engineering. If we were to model it with present-day microminiature semiconductor devices, the 'thinking machine' that copied the brain would weigh at least ten tons and cost a minimum of a thousand million roubles. But it wouldn't last the time it takes to say 'Jack Robinson' because of the unreliability of present-day semiconductor elements. It would probably burn out in an instant because the power it would require (thousands of kilowatts) would generate too much heat for such a small volume.

The human brain works at a temperature of 36.7°C and remains capable of functioning for scores of years. And its beggarly power—only that of a pocket torch—only emphasizes the modest sublimity of this most perfect of machines, and involuntarily brings to mind countless flowery metaphors—'the inextinguishable lamp of reason', 'the immortal sun of the mind', and so on.

Of course it deserves paeans of praise, this eternal white heat of creative thought, which is made reality by the work of creators and transforms the world around us.

But what about the thinking machine (*Machina sapiens*!?) that *Homo sapiens* has created in his own image? However imperfect the electronic brain still is, and however far it lags behind the human brain, it is still one of man's greatest creations. And it is it that caused a real revolution in the system of production in the middle of the twentieth century. But more about that later.

How has our '50-watt motor of progress' functioned?

What forced it to move tirelessly forward from the hunter's trap and snare to the 'thinking' machine, from the stone chisel to the walking excavator, from flint and tinder to atomic power stations, from the first wheel to spaceships; to work in the sweat of it's brow, amazed by what it has created, but never content with what it has achieved?

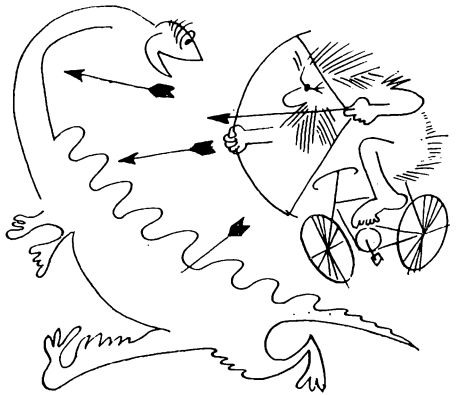
The role that productive relations play in scientific and technical progress can hardly be exaggerated. And it is obviously necessary to consider the character of the social-economic system (on which the atmosphere of creation depends), but is that enough?

Marx once scoffed at Proudhon for trying to infer technical forms from economic ones. 'Machinery,' he wrote in a letter to V. Annenkov, included in *The Poverty of Philosophy*, 'is no more an economic category than the ox which draws the plough.'

Technique has its own laws of progress, but what are they?

The driving force of development, of course, is contradictions requiring resolution, the contradictions between technology and the economy, for example. Let us call them external contradictions. What then should be considered inner contradictions?

Inner or internal contradictions are a kind of 'dramatic collision' like the conflict between tools and the object being worked with them (for example, between the wooden wedges used in a quarry and the unyielding rock; sooner or later the need to improve and perfect methods led to pneumatic drills, explosives, and excavators), or between a machine and the material it is made of (the development of aircraft called for strong but light alloys, which had to be created specially for them); between the designed machine and the possibilities of producing it (computing engines approximately the same in principle



as today's were invented back in the nineteenth century, but the gear trains were so intricate that it was difficult, sometimes impossible for them to function; electronic switches that replaced the mechanical ones brought the dream of the 'thinking' machine to fruition); between the technical basis of various industries, between various operational characteristics, and so on.

But it is impossible to consider any one of these contradictions the main driving force in the development of technique. They reflect separate aspects of the phenomenon only and not the most important one. Man and his labour must be regarded as of paramount importance.

Tools occupy an intermediate position between man and nature, which serves as the object of his labour. Man is the father of technique and nature its mother. The offspring inherits qualities from both; from one aspect it appears something dead, made of matter, created from things ('the objectified power of knowledge'), and from another aspect as part of the living, as a continuation of our bodies (artificial 'organs of the

human brain'). If we only regard one of these aspects, and exaggerate it into the bargain, we easily fall either into an idealistic 'spiritualization' of matter ('the demonic forces of machinery') or into a vulgar materialist, narrowly technical understanding of the problem in thinking of tools as things in themselves (a collection of inanimate objects and nothing more). In both cases we go to extremes, anti-human extremes moreover, because they turn into complete contempt for man.

So technique is the daughter of man and nature. And if it has 'inner' drives to its own perfection they come, paradoxical as it may seem, not from within it but from outside. But what is the inner logic of its development?

Man comes into the world with bare hands. But, unlike the apes, man knows how to make tools and change his environment and subordinate it to himself.

Man has the capacity to impose artificial organs between himself and nature, organs that can serve as a sword and shield in conflict with a hostile environment. Unlike his natural organs they submit to systematic improvement. And here his restless brain is indeed insatiable. The best is the enemy of the good; and in fact, man, who is never satisfied with what he has, ruthlessly rejects the old and out-moded for the new and progressive.

The conflict between needs and possibilities, between what we want and what we have, between dream and reality arises with man's first steps. How is it resolved?

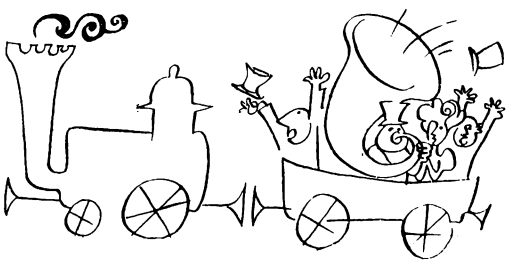
Man primarily seeks and creates what he most of all lacks, first percussion tools, then stabbing and cutting instruments, for his own anatomical structure is least of all adapted for gouging an unyielding solid, crushing or dividing it, piercing, splitting, cutting,

and scraping. Tools compensate, as it were, for the weakness of the human body, which makes itself felt in the very first clashes with the environment and in the first attempts to transform it. So the development of technique is directed by a logic of compensation and addition or supplementing.

A stick lengthens the arm, and becoming a lever, makes it stronger. A hammer is not just a fist; when made of stone it is much tougher than flesh and blood. A knife supplements teeth and nails, demonstrating the hitherto unknown sharpness of an artificial blade, especially of metal 'incisors' and 'fangs'. An arrow is also a stick, but with a sharpened point and feathered; and an arrowhead is a knife.

But what is a bow? It is a kind of narrowly specialized muscle, capable of straightening swiftly, but superior to human muscles in the length and accuracy of its throw. It is easy to draw the bowstring, but it is impossible by any kind of jumping or throwing to achieve the effect obtained when it is released.

The domestication of animals (food, means of conveyance), the clearing of land (building materials, agriculture), and the harnessing of the elements (fire, water, wind) made the weak two-legged creature a more and more powerful being, and transformed him



into a real master over nature. But however much the relationship of forces is altered in man's favour the contradictions between needs and possibilities remain, and the principle of compensation continues to operate.

The steam engine and electric motor multiplied man's strength many times over. They squeezed out the 'living engine', taking onto their shoulders the lion's share of physical work. And electronic computers are making good the imperfection of the brain and have already taken over a big whack of mental labour.

So the law of the self-movement of technique and all its development consists in replacing human exertion by natural forces, and natural instruments of production, as Marx said, by artificial ones (with their consequent transformation from human tools into the tools of a mechanical apparatus).

From that standpoint the history of technique falls into a number of qualitatively different stages. What are they?

Before we can answer that, we must first make a reservation. The principle of compensation doesn't consist simply in technique supplementing man but also in man supplementing technique and forming a kind of integral, interacting system with it. Without means of production man is, so to say, nothing; and without man, they, too, are nothing. But man supplements them only in so far as they, though dead themselves, come to life as it were and begin to function efficiently. Man forms an aggregate working mechanism with them, in which the less developed the technique or technology the more functions he takes upon himself. Before the development of engines he himself acted as a 'living motor' activating various tools. With the advent of machines he himself has become their tool, their bone-and-muscle, nerve-and-brain appendage. And only automatons

relieve him of his unnatural functions and give him the opportunity of devoting himself to a truly human pursuit, creation.

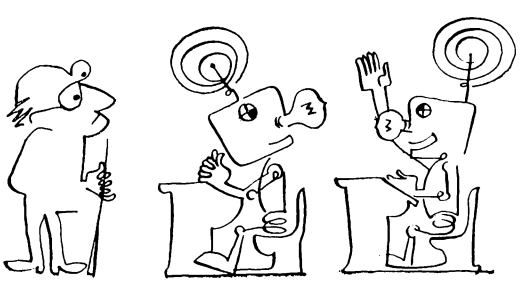
Prof. Volkov suggests dividing the history of technical progress into three stages according to the type of connection between man and machine, namely, the *instrumentalization* of production (meaning the development of the tools and instruments of labour), then *mechanization*, and finally *automatization*.

The first stage is the longest and embraces the Stone Age, the Bronze Age, and the Iron Age, that is to say about 600 000 years in all.

When did it finish?

With the development and spread of machine industry.

The transformation took many decades, but by comparison with the thousands of years of the stage of instrumentalization it undoubtedly seems a sudden leap; and it was precisely then that a qualitative change was observed in the 'man-technique' system, a real, unprecedented shift of labour functions from the first member to the second. Not only were the means of labour transformed but also man's relations with them. The instruments of labour that had previously been dead without him were now manipulated by machines.



'Now the machine, which for the worker possesses skill and force, is itself the virtuoso, which possesses a soul of its own in the mechanical laws operating in it.... The activity of the worker is defined and regulated from every aspect by the movement of the machinery and not the other way round,' Marx wrote in his *Grundrisse*.

So the vast upheaval began in the sphere of the productive forces that came to be called the Industrial Revolution of the eighteenth and nineteenth centuries.

In that case what does automatization represent? In contrast to mechanization it hands over mental work for the first time to technology, as well as physical labour. For the first time man ceases to be an integral part of the 'aggregate working mechanism'. In handing over the functions of the nerve-and-muscle appendage of the machine to cybernetic devices he is gradually excluding himself from the 'man-technique' system, rendering it completely technological, and putting himself above it instead, as it were, so that (as Marx put it) the worker, instead of being the chief agent in the productive process, stands outside it as its controller and regulator.

It is not for nothing that automation is being taken as the sign and symbol of the twentieth century and the threshold of a new civilization.

But hold on a moment! What about the cuckoo clock? And Empress Anna's fireworks? And the wonderful 'cybernetic' devices of even hoarier antiquity, that came into being long before the stage of automatization, or even of mechanization?

Hero of Alexandria described (in the first century A.D.) a whole series of 'self-acting' devices. One of them opened the door of the temple when the fire on the altar was lit. Another dispensed a dollop of 'holy

water' when a coin weighing not less than five drachmas was dropped through the slot of a cash box.

So perhaps those sociologists are right who say that automation is apparently not the last word in technology but only a new name for a phenomenon as old as the world, that began with the first hunter's traps and snares?

Of course not! The clocks, self-triggering arbalests, and other self-acting devices of the past never themselves determined the technological basis of society.

But what about the automatic machines and machine tools of the nineteenth century—lathes, printing machines, welding apparatus, and so on? They were already quite common, and there are quite a few of them today. Given a definite sequence of operations, sometimes quite complicated, they repeated it exactly each time after being started. But they are not considered automatic in the full sense of the term. A man minded or tended them. If the fitter made a mistake in setting a cutter or some other tool, or if a break occurred that the machine was not built to respond to, it would go on turning out rejects as if nothing had happened, until man intervened.

Such devices are intellectually primitive and cannot be called thinking.

The automatons of the twentieth century are quite something else. Self-adjusting (or adaptively optimizing) systems are becoming more and more common. They can remember and generalize the experience of their own working, and then use it purposefully in accordance with changing conditions, which enables them to take on most complex functions previously considered the prerogative of man—management functions, for example.

It is this kind of automation that promises the worker real emancipation, delivering him now not simply

from heavy physical toil but from laborious mental work as well, and liberating him for creative quests.

The electronic brain is still a long way behind the human one, of course, but the artificial creation, unlike its natural prototype, is being rapidly improved; and even at its present stage the 'thinking machine' is bringing about a veritable revolution in all branches of human activity, above all in the fields of production and management.

For the essence of the modern scientific and technical revolution is that man is entrusting his own direct productive functions to machines, including (and this is particularly important) his controlling, managing functions.

The employment of control machines is the level of automation that permits us to say whether any branch of industry, transport, or agriculture, or any other sphere of human activity whatsoever, has undergone a scientific and technical revolution.

On the Threshold of a New Civilization?

'The future belongs to the machine, which is replacing people in all branches of industry, even in the making of machines. It will proliferate itself, leaving the role of overseer to humans, a very limited role since electricity will take the place of the nervous system in it.'

Those prophetic words were written in 1888 by the French Marxist philosopher Paul Lafargue, the son-in-law of Karl Marx.

So, the future belongs to the machine? But surely automation is not the beginning of a new era in the history of civilization, is it? It looks as if it were. But—.

'This discovery begins a new era in the history of civilization. It may some day be more revolutionary in the development of human society than the invention of the wheel, the use of metals or the steam engine. Never in history has society been confronted with a power so full of potential danger and at the same time so full of promise for the future of man and for the peace of the world.'

Can you guess what that was written about? No one, surely, could more lapidarily describe the significance of so revolutionary an innovation as today's automatic systems, could they? But no, the compliments were not addressed to automation. Perhaps to nuclear engineering then? Again, no. To rockets? No.

Our quotation comes from a report drawn up nearly 100 years ago, in 1875, by the Joint Committee of the U.S. Congress on the Horseless Carriage. It referred to the internal combustion engine!

But 75 years hadn't passed (a short time on the scale of history) before the whole world was talking of a new era in the history of civilization, the age of atomic power. And what new era will they be talking about in another 75 years? Or in 175 years?

That brings us back again to our question, why precisely is automation singled out as the sign of a new epoch, as the road to a new civilization? Why shouldn't we put other revolutionary innovations on the same footing with it? For example, nuclear energy, tamed by man in the middle of the twentieth century? For hasn't nuclear energy also very radically altered production and the most varied aspects of our lives? It was with good reason, you see, that Einstein called it a 'new force', 'the most revolutionary thing since prehistoric man discovered fire'.

But what if we put the 'unprecedented' and 'unusual' not under the magnifying glass of wonder and awe, but under the objective of an impartial analysis that doesn't optimistically distort things?

In *Capital* Karl Marx more than once stressed that the form of motive energy had no significance for machines, that their drives did not in fact revolutionize the means of production.

The revolutionary aspect that the author of the theory of relativity had in mind was there in atomic

power, of course, but everything in the world is relative!

If we are not simply interested in the next revolution in one field of technology or another, but are concerned with the actual overturning of the whole system of production, we must not neglect Marx's criteria. The main one is qualitative change in the instruments (means) of labour, the most important leaps in the 'man-technique' system. It is man the creator who is the most valuable capital of society, who produces material and spiritual wealth in the name of man and for the sake of man; he is the beginning of all beginnings, the measure of all things, and it is he who is properly the datum point of any scale, the centre of any system of co-ordinates, if we want to get an idea of the real indices of scientific and technical progress. With that approach, giving paramount importance to the worker and his labour, that which could escape what would seem to be the most penetrating gaze becomes clear. With any other approach—well, with any other approach we can lose our bearings navigating in the complex situation of stormy scientific and technical progress with its inflation of 'new eras' that threatens to devalue the real indices of progress.

In 1920 Wilhelm Wundt, the German scholar, published his fundamental work *Völkerpsychologie und Ethnopsychologie*. In Volume X ('Culture and History') the development of technique is broken neatly down into the following stages: (1) a mathematical-geometrical stage; (2) the age of mechanisms; and (3) the age of power, opening up a new technical world. One has the feeling that the then progress of power engineering left an indelible impression on Wundt. And of course it was unprecedented and wonderful on the background of what had gone before.

Take the internal combustion engine, which opened the era of motor cars and flying machines. Wasn't it, in truth, the wonder of the age?

The electric motor stood out among engines to some extent, not because it embodied an unprecedented 'new force' quite unlike any known earlier (water, wind, steam, muscles), but simply because it was very convenient to employ. It could be given any size (and capacity) within a vast range from the gigantic to the midget. What other device was more capable than it—efficient, compact, smokeless, providing power for electric razors, vacuum cleaners and refrigerators, pumps, lifts, cranes, and machine tools?

In transport, where the internal combustion engine predominates, electric motors, which are easier to regulate, are often employed as intermediaries. Even on the atomic icebreaker *Lenin* the heat generated by the burning of atomic fuel is transformed first into electricity and then into the rotation of screw propellers.

The technical practice of our ('atomic') age has confirmed Engels' perspicacious observation, made in 1883 when, becoming interested by experiments in the transmission of electricity (over a distance of 57 kilometres), he could see in it something that the experts themselves (or at least many of them) had still not given a clear account of. In reality, he wrote to Bernstein, it was a tremendous revolution; the steam engine had taught us how to convert heat into mechanical motion, but the employment of electricity would open up the way for us to transform all forms of energy (heat, mechanical, motion, electricity, magnetism, light) into one another and back again and to apply them in industry.

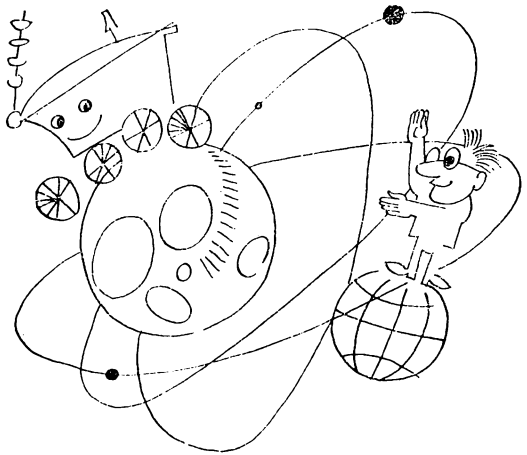
But now it is difficult to say what promises the

greater technical revolution, the breakthrough into the interior of the nucleus that so impresses us, its contemporaries, or further mastery of the electron clouds (which, as like as not, still does not belong among the epoch-making innovations).

The much-publicized 'atomic age' that began before our eyes, however, does not at all mean that the 'age of electricity' that arose in the middle of the nineteenth century is finished and done with. Remember, the high road of nuclear engineering was laid in the bed of electrification. And what about the rapid development of electronics? Without solar batteries, for example, it is difficult to imagine further progress in astronautics. And if the epithet 'atomic' applies to our age, it is probably better to understand it in the wider sense of 'electronic' rather than in the narrow (and sole) sense of 'nuclear'. There seems to be more than one 'new force' to be added to what we have already achieved in taming the electron (which has proved, in fact, as inexhaustible as the atom).

But is it worth hunting for the 'most revolutionary' of forces, as Einstein did? And for that matter, why 'forces'? Because they are associated with concepts of vast power, expressed in megawatts, if not in megatons? Is it really a matter only of the quantity of ever newer horsepower that is harnessed? What about control of this horsepower? Control is becoming more and more vital. And it is being accomplished more and more by means of semiconductor devices. Electronic devices, as well, are becoming less and less powerful but they, too, must be included in the 'new forces', these weak little midgets on whose shoulders more and more complicated tasks of controlling vast, powerful aggregates are being laid.

In Norbert Wiener's view, the invention of elec-



tronic regulating mechanisms, miniaturized, fast-acting, free of friction, responsive to light pressure on a button, enabling us to subordinate a colossus to our will with a wave of a hand, has altered the basic conditions of production as fundamentally as the transmission of power over any distance and its utilization in any place by means of small electric motors.

Electronics has given us the possibility of regulating myriads of mechanical hearts and muscles linked together in a most intricate system by 'nerves' (wires); and to control them from a single command post, which also need not be located in their direct vicinity. That is very important at the present scale of production, especially when close proximity between the technological apparatus and the people supervising it is not desirable.

Once again this underlines the whole conventiona-

lity of such sobriquets as 'the age of steam and electricity', as the nineteenth century is sometimes called in distinction from the present, to which bright-sounding labels are also customarily attached, only with words like 'atom', 'space', and so on. Has the good old steam engine really been relegated to the museum? As for electricity, it is even less ready to give up its position, for now it has become a worker by brain as well as by hand. The weak currents giving life to 'electronic brains' and the whole 'nervous system' of communications have by no means devalued the strong currents feeding the powerful musculature of electric motors, or relegated them to second place; on the contrary, they have only increased the possibilities of the latter and enhanced their importance.

It is impossible, of course, to ignore the other trends and aspects in the curriculum vitae of scientific and technical progress at the present stage. For today's scientific and technical revolution is the result of all the numerous changes that have been accumulating since society began, and brings together in itself improvements in the most varied fields.

Take the adoption of chemical methods. This is a most notable trend in scientific and technical progress. Chemistry will still astonish us and our descendants many times with its gifts—new building materials, semiconductors, medicines, fertilizers, synthetic foods, and so on. But it cannot take a single step in its technological processes without automated systems, just the same as power engineering.

The 'space age'? The launching of artificial satellites, manned spacecraft, and interplanetary stations is certainly stimulating the development of science and technology and bringing perceptible benefits to all of us (celestial meteorology, repeaters, etc.). One

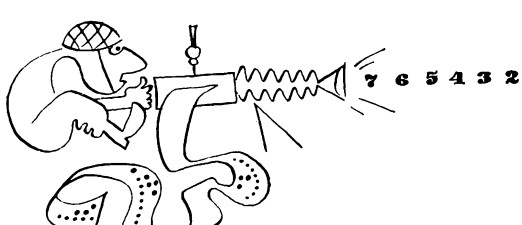
could expatiate on the role of automatic systems in other fields, as well. But what's the point? It is so well known.

Can we, therefore, consider automation simply as a trend in scientific and technical progress, along with the conquest of space, the development of nuclear power, the spread of chemistry, and so on? Or isn't it really the main trend, on which development in almost every other field depends?

If it is the main trend, it becomes clear why the start of the scientific and technical revolution is placed at the end of the Fifties and beginning of the Sixties.

The family tree of electronic computers goes back to 1945 when, within the walls of the University of Pennsylvania (USA), the Adam of computing technique, ENIAC (the Electronic Numerical Integrator and Computer) was built. That this Adam was born with a silver spoon in its mouth it owes to its military godfather. The computer was developed on a project from the Ordnance Corps of the U.S. Army, and until 1955 was used for ballistic studies.

In the Soviet Union we began work on computers in 1949. Three years later our BESM (from the Russian initials for High-speed Electronic Calculating Machine) was already working, and has been occupied, so far, with peaceful pursuits.



The 'cybernetic Adam and Eve' belonged to the valve generation. ENIAC, for example, contained 18 000 thermionic valves, which made it quite cumbersome, weighing at least ten tons.

But by 1959 the second generation of computers—the transistor generation—had been developed. Miniature semiconductor 'neurons' made it possible to reduce the size of the electronic brain and to bring its weight down to between 200 and 400 kilograms, and at the same time to increase its speed and reliability while reducing its power consumption.

At the same time the amazing possibilities of the 'thinking machine' became generally recognized, new possibilities that coincided with new demands and requirements.

Without computers it is impossible to control and manage the national economy. The calculations needed now would occupy the whole population, and plans would be ready not at the beginning of the period in which they were to be implemented but only at the end, if all the necessary operations were done 'by hand', or rather 'mentally', without machines (for our brains are really much slower than electronic ones and can only operate with ten to twenty factors at a time instead of the hundreds and thousands of a computer).

The superhuman speed of 'thinking machines' ('faster than thought'!?) has not yet reached its limits. There are already millionaires, and even multimillionaires, among present-day computers, i.e. machines whose speed exceeds ten million operations a second. And billionaires are in the pipeline.

It is not so very long since machines began to be employed in economics, in 1951, when a computer (UNIVAC-1) was installed in the U.S. Bureau of the Census. In the USSR economic calculations

have been made on machines since 1954 when the BESM-1 referred to above was used at first, and a little later the younger 'Strela' ('Arrow'). The stock of machines is growing rapidly. By the end of 1968 there were 90 000 in the world as a whole and around 30 000 building.

Thus, at the turn of the Fifties and Sixties, when electronic computers were being introduced more and more rapidly into management, a real revolution began, opening a new stage in the history of the productive forces. It is not happening simultaneously in all countries, of course, and is proceeding unevenly; and its social causes and consequences are different.

In the Soviet Union it began in the second half of the Fifties. It would have begun earlier, it should be said, but the war interfered. The prerequisites had been created during the years of the first five-year plans by broad programmes of mechanization and automatization, and by 1941 we had come close to the threshold of the scientific and technical revolution.

Hitler Germany's attack forced us to switch our peace-time economy over onto military lines in double-quick time. The peoples of the USSR lost twenty million dead, and that terrible, irreparable loss long had its effect in a shortage of personnel in industry, agriculture, and science. Over 1700 towns and urban communities were razed to the ground; institutes, laboratories, observatories, and libraries were looted and destroyed. The total material damage done to our country came to hundreds of thousands of millions of roubles.

But in spite of those colossal losses, the pre-war level of production was reached, and even surpassed, in 1950, within a few years of victory.

And in 1950 an automatic factory making piston-rings for motor vehicles had begun operation, and

then another, mixing concrete (at a thousand cubic metres an hour), and operated by only five or six engineers on each shift.

With the development of electronic computers automation entered a new phase with us in the Soviet Union. One could give many examples, but I would like to single out just one (perhaps not the most striking one, but symptomatic).

Kiev scientists developed the Vanguard system with a general-purpose control computer (UMSHN), to which was entrusted the designing and fabrication of the hull elements of ships. The new technology was introduced in one of our shipyards. The thing is to automate all the processes of shipbuilding, from project drawing to the launching of the ship.

That kind of automation is also applicable in principle to making aircraft, rockets, reactors, accelerators, or to any industry. And one day the machines will begin making themselves, improving from generation to generation. Prof. A.N.Kolmogorov, Member of the USSR Academy of Sciences, for example, does not reject the possibility, in principle, of building a self-adjusting machine capable of reproducing automatons like itself as well as setting itself tasks formulated for it by man.

Automatons as engineers and scientists are a fantasy that is becoming reality. These machines can take any instrument and independently conduct an experiment. The automation of research has already begun with the posing of such problems as, say, the analysis of photographs of the stellar sky or of the tracks of particles obtained by photographing nuclear reactions. As regards the theoretical sciences, no less interesting tasks are arising for the automation of the very processes of scientific creation. In the field of mathematics this applies above all to the proof

of difficult theorems... In twenty or thirty years such cases will probably in fact be met.'

That is the view of Prof. V. M. Glushkov, Lenin Prize winner. Work has been done under his direction that confirms the justice of his forecast. In 1958 successful experiments had already been carried out on the machine proof of certain algebraic theorems. Similar experiments were made by the American mathematician Wang Hao in 1960.

'The Russians began working on computers later than us, but they have already definitely closed the gap,' the American scientist, Paul Armour, is reported to have said in 1961 after a visit to the USSR. 'And in mathematics they have long had a well-deserved reputation. I have no doubt they have caught up with the West in general in computer mathematics.'

The other socialist countries also embarked on the scientific and technical revolution at the same time as the Soviet Union, and co-ordination of their activities through the Council for Mutual Economic Assistance is helping to direct its course.

In the United States the scientific and technical revolution began rather earlier than anywhere else in the West, in the Fifties. Its preconditions had already been laid in the first half of the century, and particularly favourable conditions for automation were created by the arms race. In 1940-4 the American monopolies received vast military orders, amounting to 175 000 million dollars. There were no unemployed; yesterday's 'surplus of hungry mouths' had been converted into a shortage of working hands. To compensate for the lack of human resources, and to ensure maximum production of machines with the minimum number of personnel, industrialists were forced to cough up the money for innovations that would have been considered unprofitable before the

war, or not promising quick returns. Automation received a powerful stimulus, and the United States found themselves on the verge of the scientific and technical revolution.

The revolution began in Western Europe under the influence of the United States, and the countries affected owed much of their post-war economic development to it. There was some basis for the talk about the 'economic miracle' in several countries in the Fifties, even in those that had been pretty well ruined by the war (West Germany and Italy).

But the most striking illustration of how the scientific and technical revolution can transform the image of a country is probably not to be found in either Europe or America, but in Asia. It is the famous 'oriental miracle' or 'Japanese phenomenon'.

People in Europe still very often think of the Japanese as people who are catching up with us, the French reporter Robert Guillène wrote in *Le Monde* in 1961, but that was no longer true. 'They have overtaken us', he said, adding that when one looked at Europe from Tokyo, Europeans seemed people dragging a load at the tempos of the nineteenth century, while the Japanese were people who were striving more quickly to reach the year 2000.

Japan, which lay in ruins in 1945, has become the second industrial power in the capitalist world in the past ten years or so. Industrial production in the capitalist countries, according to UN statistics, rose by 55 per cent in the ten years 1958-68 (and in the socialist countries by 83 per cent). But in Japan? By 245 per cent (three and a half times)!

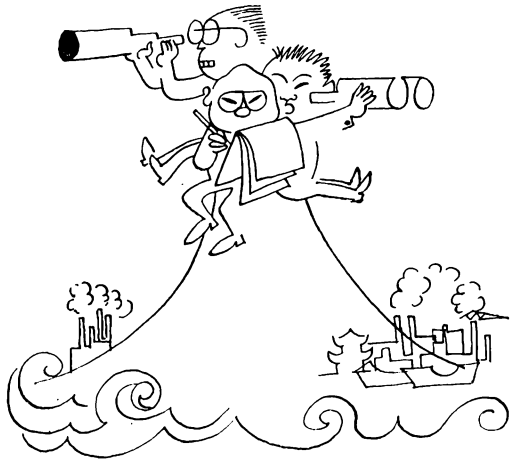
Japanese economists were declaring 'without false modesty' that the Land of the Rising Sun would outstrip the present leader, the USA, by 1990 in national income per head of population, that is to

say, would become the 'richest country in the world'; and that Japanese industry would maintain its unprecedentally high growth rates over the next five years (17-18 per cent per annum), rates very much above those of the United States (4 per cent) or even the Federal Republic of Germany (13 per cent). The oracles of coming prosperity seemed to forget that the dynamics of this development were not stable; booms gave way to recessions.

The spurt of the Sixties, the 'Idzanaga boom' (so named after the deity who, if we accept the ancient Japanese myth, made the Land of the Rising Sun the 'navel of the Universe'), began in 1965. After rising rapidly to a peak growth rate of 19.1 per cent in 1967, the pace began to slacken a little (averaging 17.6 per cent for 1967-70). But in the third quarter of 1970 growth dropped sharply to only 2.3 per cent and in the fourth quarter to 0.4 per cent, picking up to 4.9 per cent in 1971. So the 'Idzanaga boom' finished, though not quite so quickly, as the preceding 'Ivato boom' of 1958-61.

When people give reasons for the 'big leap', a top place in the long list (Japan's own insignificant military expenditure and, on the contrary, the substantial dividends from American orders linked with the war in Indochina; the high standard of technical skill and know-how of Japanese workers; and, at the same time, the relatively low level of wages; and several other factors) is usually given to a secret that is not really so very new, the art of skimming off the cream of scientific and technical progress.

Japanese industrialists keep a close eye on the market in inventions all over the world, hunting down the most promising innovations and then, instead of 'discovering America again', importing them, sparing no expense for patents and licenses.



The huge American concern of Dupont de Nemours spent eleven years and 25 million dollars to develop the process for making nylon. The Toyo Rayon Co. in Japan did it more simply. It acquired the patent. Over the nine years 1951-9 it paid out 7.5 million dollars in royalties on it, but that was recouped with interest. The company's exports of nylon alone over the same period brought it a profit of 90 million dollars. Now Japan leads all countries in production of artificial fibres.

Present-day Japan is winning round after round in its competition with yesterday's victors, who once delivered it an atomic knock-out blow. It is gaining the upper hand even in fields where the USA was once the pioneer. In production of transistor radios Japan occupies first place in the world, and second place in production of TV sets and computers. And

its products are often better than those of their American or European competitors.

Before the war goods labelled 'Made in Japan' had a reputation for shoddiness. Malicious tongues used to say that Japanese clocks were sold not by the item but by weight, by the hundredweight as scrap, and that their bicycles, which buckled under the weight of the rider, could be advertised as the best means of going straight to heaven.

It is paradoxical, but a fact, that Japan, lacking minerals, possessing no iron or oil, or other important raw materials, harnessed the first troika of metallurgists and chemists.

So it's 'skimming off the scientific and technical cream'? In a way, but not altogether. The cuisine of the 'Japanese miracle', boosted all over the world, is also based on another old recipe—rapid modernization of equipment. In Japanese manufacturing industry, for example, plant is renewed at a rate of 20 per cent per annum so that its average age is not high, somewhere around five or six years. Such forced rejuvenation of the stock of machines naturally isn't cheap; but production repays the generosity a hundredfold—to the monopolies, of course.

One can also find quite new factors in the 'miracle', in the world of ideas, for example, discoveries and inventions that have been skilfully transplanted to Japanese soil and become beautifully acclimatized there. But is this transplantation really beyond the capacity of other countries, through patent offices? Not at all, and in fact it is not just done in Japan; so the 'specific features' of the Japanese phenomenon are not so much an explanation of it, as something themselves calling for explanation.

And what about the world of things? The machines and mechanisms that are retired or pensioned off

earlier than usually in order to make way for newer, better ones? That also is a well-known way of raising efficiency; if it is most characteristic of Japan, again, why?

Perhaps the deeper roots of the phenomenon, its primary and not secondary causes, are to be found in the world of people rather than in the realm of ideas and things?

Much has been ascribed to the Japanese national character, to the industry, initiative, discipline, patience, and other estimable qualities contributing to the success of the Japanese in creative work. And it is all true, and undoubtedly plays a role. But that ethnopsychological complex also distinguished the Japanese thirty years ago when they made the sagging 'earth-to-heaven' bicycles, and when clocks with their trade mark were sold by the kilogram for souvenir-hunters and lovers of knick-knacks.

Perhaps, then, our contemporaries in Japan are quite a different breed, and have special talents of some sort that have come out in the new generations?

The American economist J. K. Galbraith is categorically against such a suggestion. Refuting it in *The New Industrial State*, he gives his own view: 'The real accomplishment of modern science and technology consists in taking ordinary men, informing them narrowly and deeply, and then, through appropriate organization, arranging to have their knowledge combined with that of other specialized but equally ordinary men.'

The organization of labour—and not just simple organization, but scientific—has now been raised to a qualitatively higher level, much above that, for example, in the early post-war years, not to speak of before the war, when scientific organization of labour was only being born.

What about management? It has also been taken into the armoury of scientific methods and technical advances in recent decades; and here the introduction of computers has special significance. Of course, such 'scientification' and 'technicizing' of organization and management is no more than the intrusion of a new world of ideas and things into the former realm of people. But this fresh blood is accompanied with something else, the introduction of psychology and sociology into the approach to organization and management, with the aim of taking the individuality of the worker into account and making a thorough analysis of the inter-relationships of individual and group.

Bourgeois research workers have talked in every key about the era of 'humanization' that has succeeded that of 'technicism' in the approach to problems of industry and industrial growth and development (the real import of this we will touch on in a moment).

B. I. Chekhonin, a Soviet journalist who was *Izvestia* correspondent in Tokyo from 1962 to 1967, gives Japanese businessmen their due in his book *Many-faced Japan*; they have a much sharper nose for the new than West European businessmen. Their rapacious alertness enables them to spot even weak shoots that promise subsequent superprofits. And in skimming off the cream of the scientific and technical revolution they have also adopted improved methods of organization and management.

'If we confine ourselves on the whole to the most clearly expressed trends in the world of Japanese business,' Chekhonin writes, 'they are, apart from the art of taking strategic decisions, an interest in industrial psychology and how to improve "communicability" between people in factories.' Is this, then, one of the main secrets of the 'Japanese miracle'?

It is not simply a matter of scientific organization of work, however, but also of automation.

As for computerization, Japan would seem to be not very successful. In 1970 it had around 6000 electronic computers, a few more than Great Britain (5000 odd), fewer than the Federal Republic of Germany (around 6500), and many fewer than the United States (70 000). But the effectiveness of the way they are employed, of course, is not determined solely by their number or quality. Job organization is also important, and knowing how to unite computers in a system of automatons and to concentrate their intellectual power on the most important fronts of the economy.

Dr. D. V. Petrov, an economic historian who was recently in Japan, divides the economic application of electronic computers there into several stages. At first they were employed as fast arithmometers in order to speed up calculations of all kinds and to reduce the number of personnel employed on such work. Then they were turned to the solution of the more complicated tasks already facing business associations and institutions. The electronic brain was promoted in rank, as it were, and was now no longer a simple book-keeper but a real economist concerned with market analysis, seasonal price fluctuations and the relation between supply and demand, and with long-term planning.

Dr. Petrov tells about the Sumitomo Bank, which (if we are to believe its President) had already in 1967, only seven years after installing its first computer, created the first centralized automated system in the world for handling financial operations. The system now covers all the 150 branches of the bank throughout Japan.

Sumitomo's clerks do not have much to do with

the massive ledgers and card indices that used to occupy shelf upon shelf in banks. When a client asks for some service or other the bank employee immediately communicates all the essential data to a computer. The electronic clerk is connected in a few seconds with a data processing centre, and when the genuineness of the signature or facsimile stamp has been checked, the appropriate code number is selected and the machine prints out all the information about the operation on the depositor's pass book or savings book and makes whatever changes are necessary in his account, which is recorded on magnetic tape. There is no messing about with paper and writing.

That is what happens at the branch office. Now what about the centre? In the metropolis of this electronic financial empire, in the data processing centre, are concentrated eighteen or so computers. That is the whole staff. Quite a few, of course, and, it must be said, expensive. But the total number of banking operations handled by them is somewhere around a third of a million every day and sometimes as many as 700 000. Quite an astronomical number of services! When the bank closes the machines begin to 'clack and clank'. In less than two hours the management receives a full picture of the day's business—not so they can admire their constantly increasing treasure, after the style of Pushkin's Miserly Knight. By no means. Here capital doesn't gather dust in mildewed chests. It is all the time in movement, in circulation. And operative information on its business activity enables the heads of the bank to keep abreast of the economic situation. Sumitomo's system made 1500 bank clerks redundant, gave savings on stationery and book-keeping sundries and various kinds of office equipment, and paid for itself in full in five or six years.

Computers have transformed Japanese industry and transport.

Traffic on the 552-kilometre railway linking Tokyo and Osaka is regulated by electronic dispatchers that control the 150 trains that are on the line simultaneously at any one time (at speeds up to 200 kilometres an hour).

'All the trains could run without drivers,' the head of the control centre told Dr. Petrov. 'But the public are still not used to the idea and feel safer somehow when they see a man in the cabin of the electric locomotive. As a rule, the driver only starts the train from the station; we stop it ourselves, from here, according to a set programme.'

Terrific, isn't it? But just let us try and look behind the smart facade, behind the scenes of the 'Japanese miracle'. There are wonderful concrete motorways; but you must pay to drive on them. So you prefer the old roads to the new ones? They are narrow and winding, and traffic jams are a daily occurrence. At peak hours you can neither drive nor walk. The rumbling herd of cars, erupting smoke, moves forward more slowly than the pedestrians. The total number of vehicles increases year by year. In 1969 there were 4 675 000 new cars (in ten years their output had increased tenfold while the situation as regards roads improved very little). And in 1972 there were 19 million cars on Japan's roads.

The boom is profiting only the magnates of the motor industry. And so long as they make profits they don't care a straw for anything else. But for the masses of the people it is turning out to be a downright national disaster. In 1969 more than 16 000 people were killed as a result of road accidents and 960 000 injured.

And what about the poisonous fumes from the ex-

haust pipes? Added to the factory smoke and the road dust, and mixed with fog, they hang over the Land of the Rising Sun like a baleful pall of death recalling the poisonous mushroom of Hiroshima.

That's how things are outside the gates of the factories. And inside? There, in the various shops and departments were to have been created all the conditions needed to make work a joy for everyone to whom Japan owed its 'economic miracle'. Not for nothing had Japanese bosses developed a passion for industrial psychology and delved deeply into human relations!

When Boris Chekhonin visited the factories of Matsusita, the uncrowned king of electronics, who has been called the 'Japanese Ford' for his subtle technological rationalism, he saw beautifully equipped shops, dazzling cleanliness, carefully considered lighting, an artificial climate—and, you say to yourself, 'a sweat system'? No, no! That's old hat!

They can't complain of heavy physical strain, the 40 000 workers, mainly women, who make the firm's famous transistor tape recorders, radios, and TV sets. Sitting for a total of seven hours a day at the conveyor they handle almost weightless mini-parts, with neat, nearly automatic movements of their hands and fingers. Close attention has been given to every element in the assembly of the product; and the conveyor belt, whose speed increases every year, importunately reminds the workers: faster, faster, faster! There is the monotony of a procedure that reduces men to mechanisms, fixtures on stools from which muscles run; and the glittering of tiny coloured parts that dazzle the eyes. But the main thing is the nervous tension. Sooner or later people begin to suffer from haunting visions.

The dispassionate statistics present a really shocking

picture. Every year one Matsusita worker in seven suffers a nervous breakdown or psychic trauma. That is thousands of mental patients! And in addition there are dozens of suicides every year.

The old physical strain is more and more frequently giving way to (or being supplemented by) an even more exhausting nervous one. People are worn out earlier. And as soon as their productivity begins to fall they are mercilessly thrown on the scrap heap.

The Tugoku Electrical Engineering Company sacks girls at 25. Why? On the grounds that at that age their production indices somehow deteriorate. Which is probably demonstrated with all the rigours of science in the studies of the industrial psychologists, for not for nothing do Japanese businessmen have such a passion for them.

Another conclusion can be drawn from these facts of course. Why not establish permitted standards or norms of intensification? Why not lighten the work, especially that of women? But how naive can you get, to pose such a question? There is no room for such sentimentality where profit is paramount, where people exist for profit and not profit for people. So a 'humanized' approach to production problems has turned out to be very real inhumanity (as if businessmen, in studying them, would suddenly become interested in the world of people and not of things!).

And what about the fairy-tale kingdom of computers, the threshold nearly of the cybernetic paradise?

In spite of a patent shortage of labour power in Japan with its hundred million population, there are many unemployed. The annual average is around five million. That is the heart of the matter.

In the conditions of maximum intensification characteristic of present-day Japan, the exploiters are no longer satisfied by any old labour reserves, but

primarily only by the younger ones, those with stronger nerves and muscles. The army of unemployed is swelled mainly by people over 35. For the present. Because Japanese businessmen, with their sharp nose for the new, would hardly fail to adopt Tugoku's experience (sacking women over 25) if it weren't for the shortage of staff. But that shortage, too, is eased by wide introduction of computers!

Electronic computers are competing successfully with the most productive workers and forcing them out of their jobs. The labour reserves are 'benefiting' qualitatively as well as quantitatively, and that is enabling the bosses to present ever stiffer demands to applicants for jobs, and to exploit those hired ever more mercilessly.

But the position of the working people in the land of the 'economic miracle' is unenviable enough without that. The calorie value of their daily diet is lower than in most Western countries. Many Japanese would like to change their pattern of eating from the 'Asiatic formula' (rice plus fish) to the 'European formula' (bread plus meat), but it is not so simple to do. Workers in Japan are paid only about a fifth as much as in the USA although their productivity is around a third or a half that of American workers.

And safety in Japanese factories leaves very much to be desired. The Land of the Rising Sun not only leads in growth of production but also in the attendant accident rate. The annual number of casualties in Japanese factories is 500 000—half a million killed and injured every year. (The nuclear bombing of Hiroshima killed and maimed around 400 000.)

A new Hiroshima! If not the atom, then the automaton. But no, neither the one nor the other! Neither the atom nor the automaton is evil in itself.

If it inflicts evil, it is only because it becomes a tool (or a weapon) in evil hands. That's how it was at Hiroshima. And, for that matter, at Pearl Harbour. And although the war was fought with the hands of ordinary Japanese and American people, we know who directed them, who was behind them, who forced millions to die for the sake of new billions of dollars or yen. We know where the roots of this evil lie that can turn the tree of knowledge into a poisonous growth. Its name is imperialism. And whatever its particular national features and character, and however much its appearance is altered by miracles of one kind or another, economic or technical, its antihuman essence remains everywhere and always the same.

Yesterday Japanese imperialism needed militarists and condemned prisoners in order to recarve the map of the world with Samurai swords and kamikadze flames, secure new sources of raw materials and new markets, and gain new millions. Today it needs managers and overseers more inhuman than the Samurai and slave-operatives more uncomplaining than kamikadze, in order, by means of economic levers, to extend their sphere of influence, win new sources of raw materials and markets, and to gain new millions in profits. The means may change, but the goals remain the same.

The USA and many other capitalist countries can boast, like Japan, of advances in this same field of computerization, for example. The development of nuclear power engineering, the study and mastery of outer space, the advances in mathematics, physics, chemistry, and biology, the theoretical and practical contributions to the gold reserve of scientific and technical progress and its grand trunk road, automation,—no one will dispute that they have all that. But how right Lenin was, half a century ago, when

he said that the development of capitalism combined the most splendid scientific and technical achievements with the refined brutality of bourgeois exploitation. 'In capitalist society,' he wrote about the Taylor system, 'progress in science and technology means progress in the art of sweating.' And commenting in *Pravda* in 1913 on Sir William Ramsay's method of underground gasification of coal, which he called 'a great scientific achievement', he wrote: 'Capitalist technology is increasingly, day by day, *outgrowing* the social conditions which condemn the working people to wage slavery.'

A wonderful new technique has matured, in fact, in the womb of the exploiter system. It bears within it the seeds of the future and belongs to the era of automation, which indeed heralds the beginning of a new civilization. But how can that be 'emancipation of the brain', if it is brought about to the detriment of the masses of the people and for the profit and pleasure of a handful of exploiters?

'The scientific and technological revolution,' says the resolution of the Conference of Communist and Workers' Parties held in Moscow in 1969, 'accelerates the socialization of the economy; under monopoly domination this leads to the reproduction of social antagonisms on a growing scale and in a sharper form. Not only have the long-standing contradictions of capitalism been aggravated but new ones have arisen as well. This applies, in particular, to the contradictions between the unlimited possibilities opened up by the scientific and technological revolution and the roadblocks raised by capitalism to their utilization for the benefit of society as a whole. Capitalism squanders national wealth, allocating for war purposes a great proportion of scientific discoveries and immense material resources.'

In the socialist countries, where there are none of these unavoidable contradictions, the scientific and technical revolution is opening up truly unprecedented opportunities for transforming nature, for creating vast material and spiritual wealth, for multiplying the creative capacities of man, and for accelerating the building of communism.

The framework of the old technology is outgrowing its old, decaying social integument.

The development of capitalist countries, of course, has raised their productive powers to such a level that they, too, like the socialist states, now have the possibility of building the material and technical basis of communism. But it is only a possibility, a potential opportunity, that exists in principle only. To make it real, one thing more is required—a socialist revolution.

That is the conclusion of the whole course of history.

'The Last, Really Revolutionary Revolution'

The formation of human society was completed thirty or forty thousand years ago, when the first mode of production, based on the use of fire and rough, unpolished stones, took shape.

A radical revolution in this system occurred with the invention of the bow, which transformed hunting and secured man's predominance over the fiercest and most terrifying animals. Polished stone axes appeared then, too, and hoes or mattacks with handles that made it easier to dig the ground. So the first technical revolution began, which lasted for another hundred centuries (from the thirteenth millenium B.C. to the fourth). It brought about a revolution in production.

The first major social division of labour occurred then. Cattle-raising separated off from landworking and, as it required skill with spear and lasso, it became a man's speciality.

Other social shifts and changes followed. Matriarchy gave way to patriarchy, marked by the development of the clan system. And so, gradually, the first

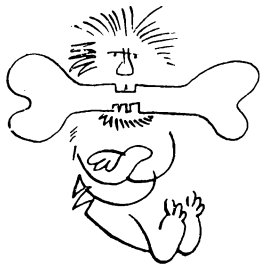
social and economic formation became firmly established. But as it reached its culmination this primitive social system already bore within it the seeds of another system—slavery.

The transition from hunting and the gathering of wild fruits to stock-raising and agriculture marked the step from savagery to barbarism, the transition to a higher level of social development within the framework of the same formation. A bit of hoed field yielded more food than very extensive hunting grounds. Now even a small family could feed itself, and so became the self-sufficient cell of society. The significance of clan and tribe as single units on which the well-being of each and all had once depended gradually diminished.

The first social division of labour promoted further development of the productive forces. By specializing on one product or another workers obtained it in quantities permitting accumulation, which made it possible to organize exchange of surpluses, which in turn entailed more significant social consequences than a simple extension of opportunities of redistributing material riches.

The more skilful or luckier family could attain greater prosperity than others, however many members they had. Inequality of possessions arose. At first it was only a slight difference, but the coming into general use of copper articles and other innovations that revolutionized production altered the situation. Those who had accumulated big surpluses could acquire better tools and weapons of metal and acquire them in large quantity so as to increase their accumulation more quickly still.

Once roused, the thirst for possessions and enrichment became unquenchable. Exchange and fraud went more and more together, and direct robbery began—



not in order to live but in order to get richer. Wars became common. And with the appearance on the scene of private property, people as well as things became belongings or chattels, above all prisoners captured by force of arms.

So patriarchal slavery was born. It became the beginning of the end of 'primitive communism'. Society, while had not known class divisions, became more and more clearly divided into haves and have nots, into masters and servants. And what is more, a new factor began to operate in history, political power based on force and concentrated in the hands of a few. Now it proved profitable to dominate in order to force one's oppressed brethren to support one.

The political organization of society was radically altered. Before it had been simple, corresponding to universal equality. Decisions were taken by meetings of the whole tribe. The elders, of course, enjoyed great authority, but in other respects were hardly distinguished from the rank and file members of the community and carried out the obligations that were normal for all. But now the leadership of society became a special job for which only representatives of the elite existing at other people's expense were eligible;

and not so much 'eligible', incidentally, as having themselves forcibly taken the reins of government into their own hands, and not as a rule because they were the most able but because they had the most—might, of course.

Copper weapons, incomparably better than stone ones, concentrated in their hands, enabled them not only to augment their possessions but also to increase their political power. Their fellow tribesmen were forced, whether they liked it or not, to submit to their rule. The victors, of course, were never satisfied with what they had achieved; and having conquered all the local communities and forced them to pay tribute and provide labour power, they waged war on neighbouring territories and peoples. That is how the Egyptian pharaohs behaved in creating their broad empire.

'The gentile constitution had outlived its usefulness,' Engels wrote in his *The Origin of the Family, Private Property and the State*. 'It was burst asunder by the division of society into classes. Its place was taken by the *state*.'

The first slave states that took the place of the simple barbarian communes were formed in the fourth millenium B.C. in rich river valleys—on the banks of the Nile, between the Tigris and Euphrates (Mesopotamia), and in the basin of the Indus (Mohenjodaro), where the fertility of the soil and the abundance of sun and moisture created most favourable conditions for agriculture.

And just like a dam that blocks the free flow of a stream so that it is turned onto fields along previously dug canals, raising the yield of the soil, the new system called forth a growth of the productive forces. Fixing the shackles of slavery on the once free labouring folk, and directing the activity of society along definite lines by means of a rigid state system, it was

able to organize the unco-ordinated efforts of people and weld them together into a single, thousand-armed force. How could isolated tribes, each clinging to its lands, even if they had gathered together the inhabitants of many villages, have built the stupendous irrigation systems thanks to which the civilizations of Egypt, Mesopotamia, and the Indus Valley flourished? To carry out such majestic conceptions a single apparatus of compulsion was required for the whole extensive kingdom of many tribes, an apparatus that provided large-scale control of human and material resources.

It is difficult, of course, to imagine a more inhuman social system than slave society. The slaves suffered brutal exploitation. Having neither family nor property, receiving only the barest minimum of subsistence, they toiled day and night for their masters until they dropped from exhaustion. Reduced to the level of beasts of burden, the slaves naturally consumed less but produced more than the free labourers of the primitive communal period, who could, to some extent, dispose of themselves, their time, their own labour power, and their own produce. That was the terrible price that was paid to raise the productivity of labour. The sweat and blood of slaves drenched every inch of the soil on which the Egyptian pyramids and other 'wonders of the world' were raised to heaven.

And what about technical progress?

Before, during 'primitive communism', any surplus of material wealth, any reserves over and above the subsistence minimum, belonged to the community and were distributed equally among all its members. And there were seldom any who were in a position to barter food or other 'goods' for costly products like copper tools or weapons. Because of the poor market,

of course, the most important crafts—mining, smelting, and smithing—dragged out a miserable existence. But with unequal distribution of wealth among separate families considerable means were amassed that could now be used to pay for even considerable outlays of craft labour. A stimulus for further technical improvements developed.

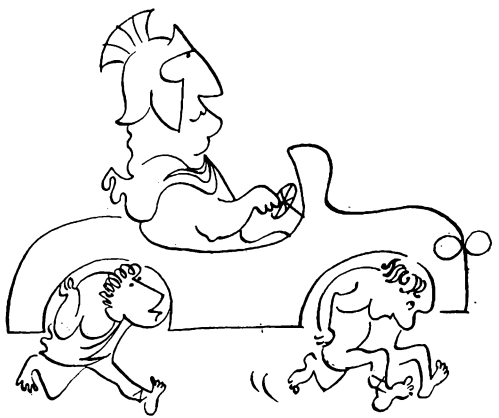
As for the technical structure, it altered little at first compared with what had already taken shape in the primitive communal system. There was a change, of course; stone retreated more and more under the onslaughts of copper and its alloys. All the same, as Engels said in *The Origin of the Family*: 'bronze furnished useful tools and weapons, but could not displace stone implements. Only iron could do that, but its production was as yet unknown'.

With the development of iron-working 'iron became the servant of man, the last and most important of all raw materials that played a revolutionary role in history' (Engels). That was a real technical revolution, the second already, and lasted 600 years (the tenth to fifth centuries B.C.). Once again the technical revolution entailed a revolution in production, again the second. It brought about the second social division of labour, the separating off of the crafts. Earlier crafts had been a sideline of landworkers and herdsmen. Now the smelting of metals, the making of pottery, and weaving became the main occupations of large groups of people; and it was crafts that gave a powerful impetus to the growth of towns.

The new technical and industrial revolution ensured the pre-eminence of the slave mode of production on a world-historical scale. But once more, not for ever! Sooner or later the contradictions between developing productive forces and the hardening productive relations began to burst the new system asunder.

With time slavery proved a brake on further progress. Take, for example, the development of handicraft production. Initially it received a powerful impetus. In the fifth century B.C. in Athens quite large enterprises already existed. More than a hundred slaves worked in some workshops (joiners, armourers), and more than a thousand in mines. It was real industry, and very large-scale for those times.

Was it progress? Undoubtedly. But how much it would have been accelerated by broad technicalization! That, however, did not happen; the masters were not interested in it. Living mechanisms, even if they were completely worn out in a few years, quite suited the entrepreneurs. That is why the water wheel, built as early as the first century B.C., waited nearly a thousand years for proper application; only in the Middle Ages, in feudal times, did it become common. In Rome, however, where slave civilization reached its apogee, this remarkable invention that raised the productivity of labour found no market.



The contradictions between the productive forces and relations of production became particularly acute during the decline of the Roman Empire. While the Caesars extended their dominions and captured more and more prisoners there were more than sufficient living machines. At times they didn't even know what to do with them; strange as it may seem, unemployment had already developed then. But as soon as the supply of slaves began to dry up, a shortage of working hands began to be felt. Then, it would seem, the hour of mechanization had struck; but alas, it needed someone to take an interest in it. And who could?

The slaves were closest of all to production, but they, illiterate, downtrodden, knowing no rest, naturally could not perfect the technology of production. Or even be interested in it. What about the free citizens? There were very highly educated people among them, but they despised physical labour ('the lot of slaves') and everything at all connected with it, even when it was the art of engineering directed to improving production.

The Romans were unable even to make full use of the technical heritage they received from the Greeks, and themselves enriched it very little. They probably have only one major achievement to their credit; they invented concrete and introduced it into civil and military engineering. But that is all. Yet Rome was by no means poor in talented scholars and engineers.

So the shortage of working hands was not compensated by technical innovations that would have raised the productivity of labour. There even began a regressive movement to the previous, almost patriarchal system. In place of the big latifundia and industrial enterprises there arose small, but more numerous, foci of agriculture and handicrafts. Gradually the ma-

during crisis of slave society (from the second to the fifth century A.D.) was brought to a head by its final disintegration, which coincided with the fall of the Roman Empire under the blows of the barbarian hordes (fifth century A.D.).

A new system, feudalism, rose directly from roots in the old, preceding one. By the first century A.D., and even earlier in Rome, the germs of a new system of production, the *coloni*, had taken root. The owner of a latifundium, wishing to increase the profitability of unfree, slave labour without any bother with new techniques, divided his land up into small lots and then rented them to his slaves, who were thus transformed into *coloni*. Possessing a certain freedom, and acquiring a family and implements, the *coloni* paid their landlord in cash and kind. Now they worked in the sweat of their brow not so much from fear as from the dictates of conscience, and toiled as neither whips nor shackles could drive them to do. Clearly that was why these farms proved more productive. They served as the prototype of new productive relations in which the feudal lord, while remaining complete master of the land and tools for working it, was at the same time the restricted owner of serfs.

As the new property relations triumphed, however, and later, too, the technical system remained for a long time at almost the same level as before; but it cannot be said that it did not alter at all. Even at the dawn of the Middle Ages, when an acute need for hands arose, the water wheel began to harness European brooks and streams. But it was still a long time in becoming adopted everywhere, and in being so improved as to become a universal engine.

The position was only radically altered in the tenth to twelfth centuries, when a new technical revolution took place. This new revolution was basically linked



with two innovations, one the wide dissemination of water wheels and windmills, and the other the perfecting of clockwork, which gave an impetus to the creation of various devices (ratchets and sprockets).

This third technical revolution gradually grew into an industrial one and brought about a transition to the guild organization of crafts in Western Europe (from the end of the twelfth to the middle of the fourteenth century).

In the Middle Ages society consisted of two classes, the almost rightless serfs, who constituted the majority of the population, and the feudal landlords, who had concentrated economic and political power in their hands. Agriculture occupied the predominant position and industry had only a secondary role. But with time its workers, town and village craftsmen, began to form a more and more influential stratum, especially after they began to unite in unions or guilds. They adopted their own rules, which regulated

the technology of production, establishing it for all master craftsmen according to the best models. Obviously, such centralization fostered the progress of industry.

The changes of a technological character were primarily expressed in division of labour between guilds. There was further specialization of knowledge and skills that favoured their separation and the rise of engineering professions. Within the workshop, it is true, there was still no division of labour, but its outlines were already taking shape. It came fully into existence only within the walls of the manufactory.

The realm of the guilds, with its free (not serf) labour and development of commodity production, was the triumph of mature feudalism; but around the fourteenth century the shoots of a new system, capitalism, began to appear within it. Free journeymen, wage workers, appeared, forerunners of the future proletariat. Embryos of the factories of the future arose and developed, in which the technological process was broken down into its separate operations, though still, of course, done by hand (*manus* hand, *faktura* making).

And from the middle of the seventeenth century, when the bourgeois revolution broke out in England (its sparks lit the flames that later swept all Europe), feudalism began everywhere to give way to a more progressive system, capitalism.

The new mode of production, however, and this is very important, was not finally victorious until a new material and technical basis had been laid and large-scale industry developed.

'Manufacture,' Lenin wrote in *The Development of Capitalism in Russia*, 'introduces division of labour, which effects a substantial change in technique and transforms the peasant into a factory-hand, a "labour-

er performing one detailed operation". But production by hand remains, and, on its basis, progress in methods of production is inevitably very slow.... Large-scale machine industry alone introduces a radical change, throws manual skill overboard, transforms production on new, rational principles and systematically applies science to production.'

The new technological revolution (the fourth) began precisely with the invention and introduction of working machines (in the eighteenth century), first in the textile industry and then in others.

As before, the new technological revolution prepared the ground for an industrial revolution, which consisted in a transition from manufacture with its hand labour to large-scale machine industry. The industrial revolution took place in most countries during the nineteenth century.

In Lenin's definition the industrial revolution was 'that sharp and abrupt change of all social relations under the influence of machines (note, under the influence of machine industry, and not of "capitalism" in general)'.

Now let us take a look at the present situation. Our contemporary scientific and technical revolution is taking place in very different countries, socialist and capitalist, in East and West, and almost simultaneously. And in both socialist and capitalist countries it has similar features. What is more, many capitalist states, as well as the socialist ones, have reached the level of development of the productive forces at which it is possible to build the material and technical basis of communism.

The growing over of the present scientific and technical revolution into a new industrial revolution, it would seem, is only a matter of time. All the main social and economic differences between the societies that are building communism and those that are still

under the heel of imperialism (moribund and decrepit but still clinging to life), it would seem, are being blotted out. That is what the theoreticians of convergence harp on about—the 'convergence' or 'rapprochement' of socialism and capitalism. Both, they say, have the same future, some kind of 'new industrial society' to which the scientific and technical revolution is leading. But is that so?

Such conclusions result from loss of historical perspective, from an inability or lack of desire to see the historical materialist laws governing the development of society, laws that have been disclosed by Marxist-Leninist science.

Painstaking analysis of social-economic and scientific-technical progress in various countries enabled S. V. Shukharkin and his colleagues to conclude (in *The Contemporary Scientific and Social Revolution*) that however dissimilar the concrete prerequisites and factors, and forms and duration of technical and industrial revolutions have proved to be in various states and nations, they have all had one permanent feature in common, that is that *the industrial revolution always and everywhere begins only after a social and political transformation*, be it a bourgeois revolution (France and Germany), semi-revolution (Japan), or reform from above (Russia and Sweden).

This condition, they emphasize, has always applied to the industrial revolution but not to the technical one, which could begin either after the social and political transformation (England, and Italy and Spain) or before it (in Russia and Sweden, and in France and Germany through the effect of England).

The further development of these countries and others confirms the general tendency described by Marx in his economic manuscripts of 1861-3, that 'the material possibilities of the succeeding form of

production—both the technological conditions and the economic structure of enterprises corresponding to them—are created in the preceding form'.

Within the capitalist system, the last of all the exploiter formations, the prerequisites for the development of a new system are, and have been, developing, a system that for the first time in history abolishes the exploitation of man by man.

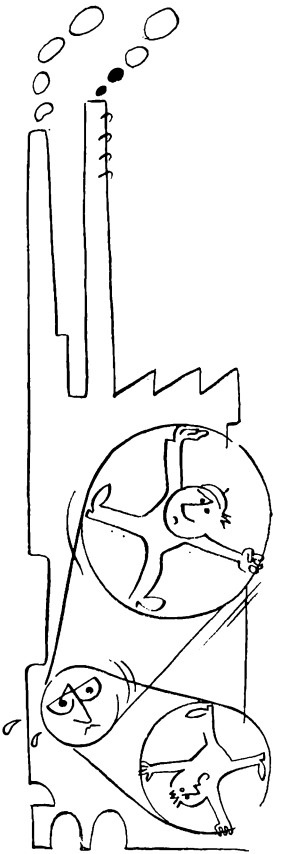
In characterizing imperialism as '*moribund capitalism*, the *transition* to socialism,' Lenin noted that 'monopoly growing *out* of capitalism is *already* the dying of capitalism, the beginning of its transition to socialism.' At this stage, within the senile organism of the old system, shoots of the future technical system characteristic of the socialist mode of production force their way through and gather strength. More than that, they develop in spite of the absence of new (socialist) productive relations; but they develop in spite of, and not due to, the old (capitalist) relations.

Now we are seeing a new result of the progress of the productive forces, a scientific and technical revolution. Beginning in the Fifties it has embraced both socialist and capitalist states; and, moreover, it simply cannot avoid involving the capitalist world. Why not? There are several reasons, but one in particular is the drive of monopolies for superprofits, and competition, especially rivalry with socialist countries.

The authors of the Russian book on the modern scientific and technical revolution that we mentioned earlier stress that this revolution is not simply a development of the productive forces, not simply rapid progress of science and technology, or something brought about by World War II or other fortuitous circumstances, but is an objective, historical process governed by historical laws. It is linked, they say, with the main thing of our time, the essence of our

age, which is the transition from capitalism to socialism, and also with the fact that the socialist countries have already actually reached the point where they are starting to built the material and technical basis of communism.

But for the present scientific and technical revolution to attain its logical completion, it must still grow into an industrial revolution, which means passing from machine and factory production to complex automated production, for which whole systems of 'self-acting' machines will be developed, capable of producing material wealth without direct human intervention of any kind in the whole of the working cycle.



You may well ask whether highly perfected automatons, and even systems, do not already exist. They do, of course, but they still do not make it possible to eliminate people from the technological chain; people still remain integral links in the chain and form an inseparable part of it. Nowhere yet in the world has man (at any rate not on a mass scale) been liberated and delivered from such direct involvement in production processes at all stages, from beginning to end.

It will be quite another situation when whole shops and factories become automatic, making devices of every kind imaginable, even very complicated aggregates consisting of many components. That kind of production already exists in embryo in the automatic transfer lines of the engineering industry. They may only be the embryo, but the progressive trend pointing the way to the future is their further development.

'Only when the production of automatic machines is taken over by automatic systems of machines,' Shukharkin and Co. say, 'will communist society have the means of production proper to it.'

A natural question arises here. Why isn't it actually possible under capitalism? Take the people of Japan, for example. Or the USA. They are gifted and hard-working, aren't they? And haven't they shown that they are capable of wonders in economics, technology, and science? And that their possibilities are truly without limit?

In science and technology they probably are limitless. As for economics—even with half a glance at the 'Japanese miracle' we can picture what lies hidden behind its impressive, and sometimes quite spectacular, facade.

Let us assume that sooner or later the Land of the Rising Sun catches up with and even overtakes America in every field, as certain oracles predict. There are various categories of the population, above all the capitalists, who undoubtedly expect to gain by it. But the main thing, alas, would not be altered, that is the exploiter nature of the capitalist system, the enrichment of one man at the expense of others, the unjust system of distributing material wealth.

But perhaps further scientific and technical progress would enable them to go over to complexly automated production under capitalism?



The new mode of production is impractical unless a whole series of necessary conditions are fulfilled. Here are some of them, in simplified form.

One, the introduction of new technology will be stimulated by the saving of living labour as a whole and not solely of its paid portion (i.e. of wages).

To put it bluntly, in raising the productivity of labour, society must be guided above all by concern for man, and for all its members. Socialist humanism rejects intensification of the kind that drains the worker of all his strength. And it is already quite impermissible to neglect safety and labour protection, whatever the cost to society.

Two, the introduction of complex automation will have to be regulated scientifically on the scale of the whole economy and not simply within the limits of single companies and their production units. In handing over the productive functions of people to machines, society may reduce not the number of people

employed but the length of the working day—again on a national scale.

Under capitalism, even with an 'economic miracle', automatons displace people, who swell the ranks of the unemployed. Those who still retain their jobs for a time with an institution or company are subjected to intensified exploitation; and they have to accept it, because they know that claimants for their jobs are always there breathing down their necks.

Three, the output of commodities, production time, and the volume and assortment of goods of every kind will have to be determined in advance by long-term planning on a national scale and not by the play of the market forces that have so often visited crises of overproduction on capitalist countries, with warehouses full to bursting, destruction of stockpiles, bankruptcies, and lockouts.

The significance of national planning, which was first practised in the USSR, is understood even by the apologists of capitalism, which is inconceivable without market forces. The American economist, J. K. Galbraith, rejects the articles of faith of his colleagues who proclaim market forces the sure and eternal regulator of social production.

'The notable accomplishments of the industrial system are all the result of such planning,' he says in *The Industrial State*, disputing the assertions of his opponents; 'there would be no flights to the moon and not many to Los Angeles were market incentives relied upon to bring into existence the required vehicles. The same is true of other services, amenities, and artifacts of the industrial system from telephone communications to Chevrolets to dentifrices.'

Galbraith would like to make his American colleagues see reason and not be like Molière's M. Jourdain, who did not suspect that he spoke prose.

At the beginning of the century Lenin had already concluded that the modern trust could give industry planned production. Later, in *The State and Revolution*, he said: 'The trusts, of course, never produced, and cannot produce, complete planning. But however much they do plan, however much the capitalist magnates calculate in advance the volume of production on a national or an international scale, and however much they systematically regulate it, we still remain under capitalism—capitalism in its new stage, it is true, but still, undoubtedly, capitalism.'

But Galbraith obviously overestimates the possibilities of the American 'industrial state' in trying to persuade his readers that it has already outgrown market relationships and all their vicissitudes, and that its chaos has allegedly been replaced by planning, not only within firms (which really is the practice in the United States) but more widely, embracing almost the whole capitalist economy.

'The magnates of capitalism cannot overcome the anarchy of production that dominates all society. And that sets definite limits to planning under capitalism,' say Prof. N. N. Inozemtsev, Member of the USSR Academy of Sciences, Dr. S. M. Menshikov, and Prof. A. G. Mileikovsky in their forword to the Russian translation of Galbraith's *New Industrial State*, stating the simple, but apparently still not wholly understood, truth. Convincingly refuting Galbraith's thesis, they show that the merger of trusts and concerns, even the merging of corporations with the state, by no means eliminates market forces, but only gives rise to new forms of monopolistic competition, in which the old contradictions, parasitism, and rottenness of imperialism stand out even more clearly.

The evolutionary transformation of capitalism into some sort of 'new industrial state' that is adopting

the all-embracing planning and other advantages of the socialist system while preserving its basis in imperialist economics and politics is nothing more than another myth of bourgeois propaganda.

Without a socialist revolution the present scientific and technical revolution cannot grow into an in dustrial revolution. The whole history of scientific and technical progress affirms that; bourgeois sociologists, however, do not shut up, but go on and on, persistently proclaiming: Historical parallels are dangerous! Humanity has entered a qualitatively new period of development! The present revolution with its dizzy tempos of change is quite unprecedented and old standards do not apply to it!

But isn't it different in principle from everything that has gone before? To begin with, the revolution is not simply a technical one, like all preceding ones, but is *scientific* as well as technical. Science has moved, for the first time, from the rearguard of progress to the vanguard, is moving in advance of technology and is becoming a direct force of production. In transforming the world of things it is also invading the world of people and human relations, and is doing so, moreover, directly and no longer 'through the door of technology'. Recall, for example, the putting of job organization and management on a scientific basis, Doesn't that really counterpose reason to chaos?!

The utopians among bourgeois sociologists pin particularly glowing hopes on the much boosted 'technocratization' of society. Real power in corporations, they say, is passing irrevocably from individuals to the group or collective; one-man ownership or management, however, is giving way not simply to committee management, but to a collegiate system in which scientists and engineers increasingly play the major role. Sooner or later, they say, this 'collective

mind', reinforced by the power of the electronic brain, will be in the saddle throughout 'industrial society', rebuilding the whole capitalist system along rational lines.

When robots replace people in productive activity, the exploitation of man by man, they say, will disappear and be replaced by the exploitation of machines by man. Antagonisms will evaporate and social harmony will be established, for the workers will only be automatons, and 'cybernetic slaves' will somehow constitute a new social class! There will be no need to fear, however, that this class will throw up its Spartacus, albeit this time electronic; the programmers should take care of that.

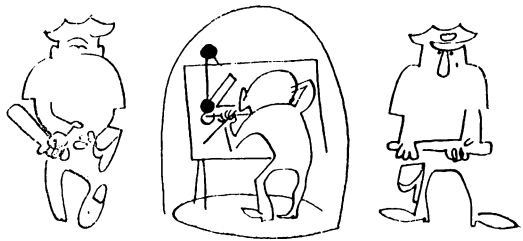
And finally the huge artificial brain will provide this new, 'robot-owning' civilization with universal plenty and everlasting prosperity.

But let us leave these pipe dreams to utopian 'sociologists'. Automation will not simply settle problems; it will also raise them. For science, of course. But the progress of science also raises problems as well as solving them!

Science is in advance of technology now and has become a direct productive force. The tree of knowledge certainly has a wonderful capacity for self-development and promises mankind fabulous wonder fruits that will bring about new revolutionary changes.

But its self-development, like development in general, needs a favourable social climate and favourable soil; and to provide that a planned society is required, however paradoxical the juxtaposition of 'planned arrangement' and 'invention' or 'discovery' may seem.

Discoveries are probably so called because they are the result of 'journeys into the unknown', finds, the unexpected, sometimes completely unforeseen even



in their general outlines. But they are not born of themselves. They are made by people; and most of them are not made by amateurs but by professionals, whose names are legion, for there are millions of them, scientists, engineers, and technicians. They work in thousands of different institutions and enterprises. It is a very real industry, not some sort of cottage or handicraft affair, guild industry or manufacture, but, so to say, machine-factory industry. And though industrial production is still only becoming imbued with science, research and development are already highly industrialized with computers, accelerators, nuclear reactors, electron microscopes, research ships, rockets, sputniks, and interplanetary stations. Capital investment in this branch of the economy is already measured in astronomical figures and continues to mount, growing more rapidly than in many other spheres of human activity.

If we understand science—a direct productive force of society—not simply as results (a collection of discoveries and inventions) but as a process (the obtaining of new knowledge) then obviously we must be concerned with the careful organization of this industry, and its continuous growth and incessant change, both quantitative and qualitative.

If it is to yield the maximum results, it cannot be left to take its own course, however great the promise of the self-development of the tree of knowledge. We cannot manage without a planned approach to the character, volume, and range of the products turned out, to expenditure on this industry, and to its labour force and material and technical requirements.

It is one thing when such planning is done in secrecy, within each firm, often surreptitiously, with inevitable duplication, in conditions of rivalry and competition between monopolies and fear of industrial espionage. But it is quite something else when planning is carried out for the country as a whole, when the creative efforts of researchers are co-ordinated on a national, even an international, scale.

It is quite probable that this difference between the socialist and capitalist systems will begin to tell in the next decade or so—yes, in the next ten or twenty years, when the disproportions may become greater and begin to show in the growth curves.

But rather than speculate on what the chances are for the one society or the other to resolve these contradictions, let us trace the evolution of science as a productive force from its very origin. We will then see that, however significant an effect science exerts on society, its opportunities of doing so are determined in the long run by the position it occupies in society.

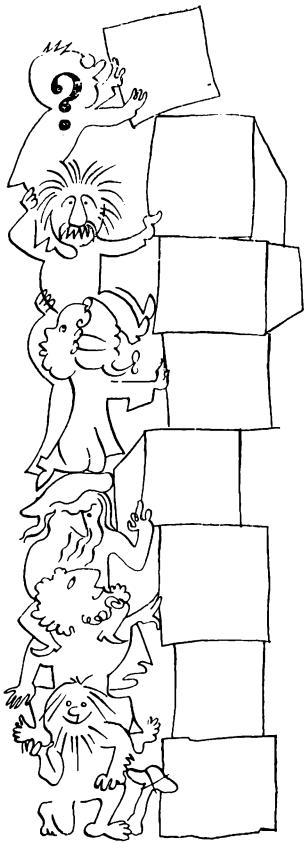
Mighty and—Powerless

It seemed that the Pharos lighthouse would raise its fiery crown to heaven forever. Erected in the third century B.C., it served for centuries as a beacon for Mediterranean *kibernetes* (as Greek steersmen were called) to steer by. But time took its toll. And 700 years ago already only the lower part, not more than 30 metres high, remained of the once majestic structure.

The architect who designed this marvel recorded on the walls of the lighthouse, as ordained, the name of Ptolemy, the then ruler of Egypt. 'Ptolemy dedicates this to the saviours, for the benefit of sailors.' Centuries passed. The plaster peeled off; and underneath it was discovered an inscription as fresh as if it had just been carved. 'Sostratus, son of Dexiphanus of Cnidus, dedicates this to the saviours, for the benefit of sailors.' So the famous engineering masterpiece named its real builder. But has nothing remained of the former wonder of the world, other than the name of the architect?

Its stones survived the people, both Sostratus and

his assistants. But something else proved more eternal, truly immortal. Knowledge, the ability to create.



Unlike Sostratus' stone brain-child, knowledge has increased in stature, raised its head higher and higher. Is today's progress in high building conceivable without it? And what does it matter, if the beacon of the ancient Alexandrian pillar has gone out? The lamp of knowledge is inextinguishable, drawing into itself all the flashes of human genius of all times and all peoples in order to burn ever more brightly and ever more strongly and illuminate the dark of ignorance and the gloom of the unknown. Is that not the real wonder of wonders of the world?

Yes, it is certainly something worth admiring and raving about, this intellectual relay of the generations, but—in being handed down from epoch to epoch, from nation to nation, as if it did not in the least depend on 'transient factors' (neither on its own time nor on the people bearing it)—the passing on

of torch of learning acquires a kind of mystic independence in the eyes of some historians of science, an invincible force that allegedly will guarantee irresistable movement in the future, without let or hindrance or any kind of social barriers, toward new triumphs, surmounting all the shortcomings of any society, even of capitalism, which has outlived its time.

If we want to understand what Science is in general, but in particular as a productive force, we would be wrong to forget its creators; and their activity cannot be considered outside time and space, for it takes place in concrete historical conditions.

Ours is not the first decade in which philosophers have argued about what science is and to what to attribute it—whether exclusively to ideal factors or, in fact, to material, technical, industrial ones. There is a very commonly held opinion that science is nothing but a form of social consciousness, an element of spiritual culture. 'That point of view could only have arisen from a concept of science as something static, as the sum total of knowledge, which can be at some one level or another, either in the basis or in the superstructure. From the standpoint of formal logic, this "shelf philosophy" is irreproachable, but it will not support criticism as regards the facts of reality,' says Prof. Volkov, debunking 'the simplicity of genius' in the treatment of such a complex business as science.

Real science, in our day, unlike its predecessors in earlier times, has an experimental character. But how to squeeze an experiment—not the result, but the process!—into the procrustean bed of a scheme that considers science 'a system of knowledge'? Yet there are philosophers who 'exclude' experiment from the 'system' for the sake of their scheme. Science without

experiment, however, is like a symphony without a performance, a score without concern for musical instruments, as Prof. Volkov puts it in *The Sociology of Science*. With such an approach, moreover, the composer himself slips out of our field of view; the living man and his creative personality disappear and all that remains is a faceless name on the title page. But how can one 'erase' its workers from science, and from its essence, research?

To reduce science to knowledge, to a world of ideas without people, means, does it not, to bring grist willingly or unwillingly to the mill of the 'technical fetishism' ridiculed by Karl Marx. The alienation of discoveries and inventions from their authors (and it is made much easier now when the authors more and more frequently prove to be whole teams in which it is not easy to determine the contribution of each individual) is quite natural in a society based on market relationships in which (in Volkov's words) 'the end product of activity acquires a false importance in relation to the activity itself, and is counterposed to it as something self-sufficient. And corresponding to the antagonism of social life there is a rupture of conceptions of it, in which practice is opposed to theory and material production to spiritual.'

Science is not knowledge for its own sake but an activity of society aimed at obtaining knowledge, in other words, scientific production or an 'industry of ideas'. It is difficult not to agree with Prof. Volkov, when he says: 'To reduce science to knowledge is equivalent to identifying the process of soap-making, say, with soap. (Is that not why, incidentally, the blowing of soap bubbles of erudition has not been considered a sign of real scholarship since Heraclitus, who said that knowing a lot did not mean being wise?).'

The conception of Science as Knowledge is an echo

of the past, of times when it had still not become experimental and based on experience, when it was predominantly contemplative and speculative, when its creators saw it as their task solely to explain the world, constructing a picture of it in their heads, and not bothering to check their abstract schemes by experience or experiment, although it is practice that is the criterion of truth.

As Engels said in *Dialectics of Nature*, modern natural science dates from the last half of the fifteenth century. It was then that exact experimental study of nature became finally established, and with time, probably from the period of Galileo (the end of the sixteenth century and beginning of the seventeenth) became firmly wedded to an investigatory approach. It already employed not only contemplation and reasoning leading to speculative conclusions, but also experimentation—and not simply experience or experiment in the broad sense of the word, but experiments arranged by man in order to test some idea, hypothesis, or theory. It is in this that experiment differs, say, from passive observation of natural phenomena occurring spontaneously.

The periodization of science proposed by Prof. Volkov has its points. It takes the time of Galileo as a kind of historical Rubicon. Before then everything is only the making of science; afterward it is the formation of a new quality in science, science as a productive force in society. What do the two stages represent? With what, for example, does the first stage begin?

Science developed gradually, along with human society. But it could not develop straight away with society, as some philosophers suggest.

When we understand science as the specially organized production of ideas, it is natural that it should

have evolved later than the production of things (although one cannot say that mental labour began later than physical, for the human brain has always acted in concert with the human hand).

It was when the scattered, disconnected elements of knowledge were united in a system, when their accumulation and production became the special job of certain members of society, Prof. Volkov thinks, that we can speak about the birth of science and the development of a special social stratum, that of scientists. In fact, the isolation of knowledge begins with the separation of mental work from physical labour and the rise of class stratification in society.

Society had first to raise the production of material wealth to a certain level permitting reserves to be accumulated before it could allow any group of the select, however small, to free itself from earning its own food and other means of existence, to free it so that it could extract valuable grains of information and obtain a quite unusual product, inedible but helping to feed the hungry, immaterial but necessary for the fabrication of articles and things of prime necessity, including tools and weapons.

The tree of knowledge and its numerous branches, of course, developed unevenly. Some shoots appeared before others. But which of them developed first of all? Medicine? Astronomy? Mathematics?

The first to evolve was philosophy, springing from roots in the soil of mythology. It was called forth by the tormenting thirst of the mind, inflamed by the countless riddles of life. What am I? What is he? or she? What are they? What is man? And what is the nature around him? What is his proper place in the world? Or ours? Or mine? At first this spiritual thirst was quenched, naturally, with the turbid froth of mysticism, as churned up by the inexhaustible foun-

tain of fantasy, and long mixed with the crystal clear, life-giving spring of knowledge.

As will be seen, science was oriented on man from its first steps, and its main function was to explain the world. It remained that way for ages, right down to the time when capitalism appeared in the arena. Bourgeois society, with its mercantile and utilitarian spirit, discovered deeply related features in evolving natural science. Then, too, technology, the production of material wealth, and the development of property gradually usurped the centre of its interests. Forever? Not at all!

'Natural science will in time subsume under itself the science of man, just as the science of man will subsume under itself natural science: there will be *one* science.'

Citing these prescient words of Karl Marx's from his manuscripts of 1844, Prof. Volkov argues that the forecast is already coming true; a direct turn in science toward man, and with it toward the integration of the natural and social science, is not far distant. 'Whereas socialism and communism make man, not the means, but an end in himself, and put him at the centre of all the living activity of society,' he wrote in the Soviet journal *Problems of Philosophy*, 'and whereas the final aim of material production is becoming production to satisfy the needs of man rather than production for profit, science is having to change its orientation correspondingly.' This change in the main social orientation of science he considers the most important feature of the present scientific and technical revolution.

But let us go back again from the second half of the twentieth century to the Stone Age. Astronomy and mathematics matured within philosophy. With time they budded off from the maternal organism. And

quite long ago, still in the Stone Age, six thousand years or more ago, the Egyptians already had a calendar and planned their agricultural work according to the flooding of the Nile. And the Pyramids? Their layout and erection were unthinkable without mastery of the elements of geometry, arithmetic, and mechanics.

It is plain that, at the dawn of history, man already had a quite respectable stock of scientific knowledge. And with each succeeding era, of course, he added to it. But our excursion into the past was not made just to establish that. Remembering that science is above all activity, the processing of information, we cannot limit ourselves to a simple listing of its results for each historical period, in order once more to convince ourselves that the sum of knowledge multiplies in the course of time according to a definite law (exponential, say, or some other form). We should not forget those who were concerned with producing this valuable product, and consequently with their relations with society, on which their position and their creative activity depended, and also the degree to which they achieved results, and whether their opportunities were restricted or not.

Is this the 'self-development' of science? Yes, it is. There was, and is, and will be such a thing, because the number of new discoveries and inventions grows proportionally to the sum total of the knowledge inherited from the preceding generation. In other words science does not simply advance through technical demands; but even if it really advanced 'independently', it would still, of course, not be by 'the will of Providence'. Someone must move it forward! And it is quite clear who does it—people, scientists. And in relation to them the well-known adage is fully

applicable that it is impossible to live in society and to opt out of it.

We have seen that the technical revolutions that have been followed by industrial revolutions have always and everywhere been closely linked with a change of social and economic formation. What about the scientific revolution?

At first glance the link is not so close. And in any case we do not know of any scientific revolutions in either the primitive communal system or the slave system. The first scientific revolution occurred a thousand years after the first technical revolution, during feudal times, and only in its very late stage, the Renaissance. Nevertheless, if one looks attentively at the past (it has been called, not without reason, the 'mirror of the future'), it will be seen that scientific progress has always been linked with social advance and depended on it.

We have already said that science had a predominantly speculative and contemplative character for thousands of years. But why? For even its first steps were generally directed toward vital practical ends! Let us recall geometry. Its very name gives its origin away—'land measurement'. Similarly, astronomy—'hovering in the heavens'—has from ancient times satisfied very earthly needs (stellar orientation in navigation; the calendar in planning agricultural work).

But in so far as mental work, with the class division of society, became more and more separated from physical labour a greater and greater mutual estrangement gradually developed between theory and practice. The social climate of science was primarily guilty of that.

The very first guarantee of successful research is not so much the will or the desire, of course, as knowing how to go about it. But however often or seldom

ability for this specific form of creative work is encountered, the probability of its appearance is never dependent on birth or origin. However lavishly or stingily Nature bestows it she endows members of all social classes with it in equal degree.

The whole point, however, is that even one lone talent needs special conditions favouring its development.

In the period of slave society, it is clear, science remained the prerogative of a secure and leisured minority; only this minority could afford to spend time, effort, and means on education and the acquisition of knowledge. But these people were extremely far removed from production and were not concerned with its needs, while those who were directly involved in it, slaves and artisans, had neither the education nor the leisure. Nor the desire. The unfree were not interested in improvements that enriched their masters, while the enlightened elite despised work—'the lot of illiterate slaves'—and everything connected with it. This 'aristocratic spirit' poisoned the outlook of most scientists of that time. Thus, Archimedes (third century B.C.), the great mathematician and mechanician of antiquity, author of famous inventions (according to Plutarch), considered 'as sordid and ignoble the whole trade of engineering and every sort of art that lends itself to mere use and profit. He placed his whole affection and ambition in those purer speculations where there can be no reference to the vulgar needs of life, studies... in which the only doubt can be whether the beauty and grandeur of the subjects examined, or the precision and cogency of the methods and means of proof, most deserve our admiration.'

Even those who had a lively interest in technique concerned themselves with its problems more as a kind of 'mental gymnastics'. They exercised their

talent more on clever knick-knacks, mechanisms like those described by Hero of Alexandria—the automatic holy-water dispenser, for example, or the steam turbine and the windmill. Most of the improvements that advanced production then were made by nameless artisans.

All well and good, you may say, but what has all that to do with the self-development of the tree of knowledge? There's no arguing about it; science can progress without outside stimuli from, say, technology. That is the way philosophy advanced, for example; and it preserved its priority among the various disciplines for a long time. There was long an illusion that it embraced every field of knowledge, a view that persisted right down to Newton's day. The task of understanding the world in order to change it had not yet moved into the foreground (applied geometry and mechanics did not determine the face of science as a whole).

Nevertheless, even here the gap between science and practice had its effect (and once more was encouraged by the prevailing social conditions). Abstract contemplation was the undoing of Greek natural philosophy. Scorning life-giving connections with experiment and experience, the source of new ideas, and with production, the bottomless well of new problems, this self-sufficient science, sensitive to stimuli from within rather than from without, existing in itself and for itself, simply exhausted itself and withered like a plant deprived of fertile soil and feeding only on its own juices. Sooner or later its priests would have run through all the possible combinations of then existing speculative concepts.

The same applies to Roman science, which inherited from Hellenistic science not only its notable fruits but also its slave-owners' spirit.

The periods of flowering and withering experienced by the tree of knowledge are not governed by the 'accidental flashes and fadings of human genius' as some idealist and metaphysical 'sociologists' assert. The deep roots of this process have been revealed thanks to the Marxist, dialectical materialist approach, the illuminating optics (as it were) of historiography.

In 1965 the enlarged, second edition of S. Lilley's *People, Machines and History* was published in London. Looking at the creative biography of mankind from the angle of historical materialism, the author argued a truth that is not new to us, that a class-divided society 'did not ensure uninterrupted progress but at times retarded technical advance for long periods'.

We must give class formations their due, of course. We have already alluded to the advantages of the system of slavery over the preceding classless, primitive communal system. The enrichment of the minority at the expense of the majority, as we have said, led to the accumulation and concentration of property in a few hands and opened up possibilities that had previously not existed. The rich exploiters paid for articles of every complexity, even extremely expensive ones; and whereas the most skilled craftsmen had formerly worked at their trade by fits and starts because they had no assurance that it would feed them (agriculture or stock-raising, which supplied one's daily bread directly, without barter or exchange, was a surer source of livelihood!), the experienced smith or weaver could now devote himself wholly to his craft, knowing that his product would always find a market. Crafts became hereditary and populous, workshops developed, and the need to improve technology and equipment became more and more urgent.

The conditions for a further division of labour had, it would seem, accumulated. Just as in olden days the crafts had separated off from agriculture and stock-raising, so now mental work could be isolated within them to some extent from physical labour, also for the good of production. The man with the talents of a scientist or engineer could, in principle, carry on investigations, provided someone gave him all he needed. And such opportunities existed in slave society. The question is whether they were utilized. And the answer is: very, very little. In any case no one would dream of freeing one of the despised unwashed, or even one of the self-taught craftsmen, be they Solomons, of concern for their daily bread; consequently they could occupy themselves only sporadically with invention.

True, mankind owes it to the slave states that a special stratum of professional scientists (in our present-day sense of the word) was first formed in them. These people, unlike those of independent means who devoted their private resources and leisure to researches, received material reward for their activity. They were very real workers, who sold their labour, but their mental powers not their physical strength. Archimedes, for example, was one of those whom the ruler of Syracuse supported as his advisers. Euclid and Aristotle were others who were also invited to royal palaces. But they were rare exceptions.

In general, all the scientists of those days, whether they considered themselves professionals or amateurs, constituted a not very numerous and not very stable sub-stratum. If we reckon up all the in any way famous names that have come down to us, they add up to a hundred or so in the more than a millenium of the antique era (including the Roman period). But that is a great many when we take into consideration

that science, which initially experienced an upsurge with the establishment of slave society, continued to develop in spite of, rather than because of, the social conditions of the system. 'If the tales of the fame won by Archimedes among his contemporaries are true, it is also true that the Roman soldier who found this scholar engrossed in a mathematical problem killed him without compunction.' So Prof. Volkov characterized the attitude to science and scientists in antiquity. (Plutarch wrote that the words 'Greek' and 'scholar' were contemptuous epithets among the Romans.)

'There is no need to recall,' Volkov says further, 'that in the dark Middle Ages the work of scholars (if they were not theologians) was valued less than ever, earning them the stake and fire of the Inquisition, that at best "necromancers" and "alchemists" were the object of universal mockery, and that the priests of science were not honoured, even by their disciples.'

You may well ask how that was. For feudalism was a blessing compared with the slave-owning formation, just as it in turn was an advance on the path of social progress compared with the system of primitive communism. Why, then, is it common to speak of the 'Dark Ages' and about a social climate unfavourable for the tree of knowledge? It is not a simple question.

It is true that the Middle Ages, at least the early period (sixth to tenth centuries A.D.) did not yield a single new discovery or invention, or any significant advance of production. And yet it would be a mistake to think that the first steps of feudalism meant only regression for society.

Lilley, for example, does not agree with those historians who picture the Middle Ages as completely 'Dark Ages', '...in which little progress was made

till, in a rather magical "Renaissance", men rediscovered the arts and sciences of Greece and Rome' ('preserved in a petrified condition')... 'and thereupon began a return to "civilization".' In the ancient world, he recalls, science was 'the prerogative of a few rich and leisured men. They were not true indexes of the level of civilization. If we look back beyond them to consider the way in which mankind in general lived, we find a different picture of the Middle Ages as an era of renewed advance after the long period of comparative stagnation.'

There is no disputing that the soil feeding the tree of knowledge in that transitional period became rather less favourable, if only because the centre of social life shifted from the towns where it had been in Greece and Rome to rural localities as it had been in Ancient Egypt and other countries of the East. The millions of people in the barbarian kingdoms that arose on the ruins of the Roman Empire lived in thousands of villages scattered all over Europe. There were no towns except a comparatively few decayed Mediterranean ports and certain other cultural centres that stagnated, half asleep. For the economic basis of society had become the manorial system with its self-sufficient local centres of natural economy where, as of old, manual labour predominated everywhere, in field and workshop.

The feudal serf, of course, had little interest in improving his tools and skills, little interest, but all the same more than a slave. And whereas the classical system was unable to utilize the promising inventions that it had at its disposal (e.g. the water wheel), the 'Dark Ages' were marked by the first spreading of the machines whose use had previously been prevented by the wide use of cheap slave labour.

So feudalism gave a powerful fillip to the develop-

ment of crafts and trade. And it led to a hitherto unprecedented urbanization, beginning in the tenth and eleventh centuries. The following figures give an idea of its extent. In mediaeval Germany alone there were 2300 towns, more, probably, than in the whole ancient world.

It was then, too, in the tenth and eleventh centuries, that a change is to be noticed that turns out to be a new step on the path of progress. It was linked with the maturing of feudalism and its transition to a more developed, higher phase. The towns that were springing up in Europe became centres of crafts and trade, and then (in the twelfth and thirteenth centuries) fought for their independence in a fierce struggle with the landowners. Master craftsmen who specialized in wares of one kind united in guilds. Defending the interests of the craftsmen, but at the same time controlling them and forcing them to improve the quality of their goods, the trade unions helped to improve tools and instruments and technology. Later, it is true, during the later Middle Ages, guild rules, become ossified prohibitions, proved a brake on the further development of production, but until then they stimulated invention.

Science was also revived. It was still fated, of course, to spend a long time disentangling itself from the coils of scholasticism, love of fruitless philosophizing, pedantry, empty contention over words completely cut off from reality. It was still a long time—not until the Renaissance—before Europe breathed new life into the petrified heritage of antiquity; but even before the Renaissance living, creative thought had not sink into a deep lethargy.

The eighth century is the so-called Dark Age, but it was then that the 'new Athens' arose, this time a 'barbarian' one. Anyway, that is what they called

the circle of enlightened people organized around the court of Charlemagne by his teacher Alcouin, the English churchman and mathematician. In the tenth century another churchman Gerbert (Pope Silvester II), author of several treatises, won fame as a mathematician. He was one of the first Western scholars to travel to Moorish Spain, where he studied Arabic mathematics (which was then at a higher level of culture than European).

Let us, too, go East.

In the ninth century the Caliph Al-Mamoun built a House of Wisdom in Baghdad with a library and an observatory. The work of the mathematician and astronomer from Khiva, Al-Khorezmi (Alkarismi), belongs to the same century. He laid the basis of algebra and gave it its name. His own name is immortalized in the now common term 'algorithm'.

That period, and even more the one that followed, is noted for a whole constellation of luminaries of the first magnitude. There was the famous Tajik natural scientist and poet Ibn Sina (Avicenna) (tenth to eleventh century), and the Khorezm scholar and encyclopaedist Biruni, the greatest geographer of the eleventh century. There was the Tajik Omar Khayyam (eleventh to twelfth century), a mathematician of genius but famous above all as a poet. And there was the great Ulug Beg, the Uzbek astronomer who, in the first half of the fifteenth century, built a marvellous observatory in Samarkand and carried out a series of observations that immortalized his name.

The list of the coryphaei of the Middle Ages is dominated by scholars of the East; only in the tenth and eleventh centuries did the epicentre of science begin to shift from East to West. During the greater part of the Middle Ages Western Europe was by no means the most advanced region of the world. Byzantium

had preserved the traditions of the culture of Greece and Rome to a much greater extent; the West took them over only at the end of the Middle Ages. And the states of the Arab East had long been several centuries in advance of the West, but they all finally fell into a decline. And mediaeval Europe, adopting advanced ideas, discoveries, and inventions from others and adding its own contribution, created a civilization based on machines, the forerunner of the present.

Florence became one of the starting points of the Renaissance. But it is false that Florence of the fourteenth century was born of some 'invigorating cultural isolation' (as Dyson says). If anyone was noted for hostile seclusion, it wasn't the Florentines. They maintained the closest links with the outside world, conquering it not by force of arms but by good cloth and sound florins.

In the twelfth century Florence had already become a republic, an independent commune. And in 1293 the serfs were emancipated, the nobility deprived of political rights, and all power in the commune vested in the guilds. The 'middle classes' advanced to the forefront of political life, the master craftsmen, the merchants, and the bankers, the forerunners of the bourgeoisie. Democratization, as once before in Athens when it adopted the first constitution in history in the fifth century B.C., also created a favourable social atmosphere for creativity.

And if Florence became the birthplace of the Renaissance, it was primarily due to social and economic progress within the framework of feudalism, which prepared the soil for a real cultural revolution. There is good reason why it was there, in Florence, the most advanced city-state in mediaeval Europe, that capitalism first arose (as long ago as the fourteenth century!).

The Renaissance, and its magnificent flowering of the arts, crafts, and sciences, was no chance, accidental 'flash of West European genius', no windfall of some sort for humanity from a lucky ticket in the 'biological lottery'. It would be wrong to think, as is said, that, if strong personalities ('giants of thought') had not appeared, there would not have been the mighty splash of the Quattrocento and Cinquecento (fourteenth and fifteenth centuries). It was not the giants who created the epoch but the other way round; the times, needing them, brought forth such giants as Leonardo da Vinci.

Of course, if Leonardo the artist had not lived there would have been no Gioconda. It is improbable that anyone else would have painted just that masterpiece with the enigmatic smile of the Mona Lisa and its quite unique features, in which the specific lines of the great maestro's subjective perception are imprinted. But that is art!

What of science? If Leonardo the scientist had not lived his discoveries and inventions would have been made by others, sooner or later perhaps, but certainly so.

'The Renaissance', wrote Antonio Gramsci, founder of the Italian Communist Party, 'can be regarded as an expression in the field of culture of the historical process during which a new class of intellectuals evolved who became of European significance.'

So the Renaissance was nothing but the natural consequence of an objectively conditioned historical process. It was the inevitable result of the evolution of feudal serf society, giving rise to capitalists and proletarians, and with them to a stable substratum of intellectuals, including scientists.

It was then that this latent flowering began.

'Modern natural science,' Engels wrote in his *Dia-*

lectics of Nature, 'which alone has achieved all-round systematic and scientific development, as contrasted with the brilliant natural-philosophical interactions of antiquity and the extremely important but sporadic discoveries of the Arabs, which for the most part vanished without results—this modern natural science dates, like all more recent history, from that mighty epoch that we Germans term the Reformation, from the national misfortune that overtook us at that time, and which the French term the Renaissance and the Italians the Cinquecento, although it is not fully expressed by any of these names. It is the epoch which had its rise in the last half of the fifteenth century'.

Engels' description of this turning point begins with a description of the social and political change. 'Royalty, with the support of the burghers of the towns, broke the power of the feudal nobility and established great monarchies... within which the modern European nations and modern bourgeois society came to development.'

The new flourishing of science and art is most clearly examplified in the work of Leonardo da Vinci (1452-1519), who was not only a great painter and sculptor but also a great scientist and engineer. His notebooks and sketches (5000 pages!) amaze one by their encyclopaedic character. They embrace the most varied problems and fields, from painting and drawing to geometry and astronomy, physics and geology, botany and anatomy. The credit for many inventions is Leonardo's, including machinery for hydraulic and military engineering. His schemes for flying machines and apparatus (helicopter, ornithopter, parachute) are interesting, outstripping his own times by whole centuries.

This giant of the Renaissance is of interest to us not solely for the power and many sides of his genius, or even in fact, because of it. Like phenomena can also



be found in the history of antiquity (Archimedes, for example!); but even with the coryphaeus of coryphaei of Greek science there was characteristically a counterposing of the leaves and roots of the tree of knowledge, a separation of theory and practice later reduced to absurdity by the mediaeval schoolmen. Leonardo's work, however, symbolizes the revolt against that old antagonism. It was his firm conviction that experience and experiment (combined with mathematics) should serve as the foundation of any scientific system.

The triumph of the experimental approach, and the spread of exact quantitative methods in theoretical disciplines signified a veritable revolution. We see here what in fact is the first scientific revolution. But the new natural science 'still had to win in struggle its right of existence' (as Engels put it).

True, as Engels said 'the dictatorship of the Church over men's minds was shattered'; and with Coperni-

cus and Leonardo modern natural science began to rid itself of theology, though it still faced a long and painful struggle to emancipate itself from the shackles of religion and the power of the Church.

Copernicus' work *De Revolutionibus* was put on the index of banned books by the Papal curia. And for the next 200 years or so the professors of the European universities were ordered, before being appointed to their chairs, to take a solemn public oath that they would not disseminate the Copernican heresy. And in this perennial witch hunt the Reformed Church (e.g. the Calvinists) were no whit inferior to the old Catholic Church with its classical instrument of repression, the Inquisition. 'It is characteristic,' Engels noted with bitter sarcasm, 'that Protestants outdid Catholics in persecuting the free investigation of nature. Calvin had Servetus burnt at the stake when the latter was on the point of discovering the circulation of the blood, and indeed he kept him roasting alive during two hours; for the Inquisition at least it sufficed to have Giordano Bruno simply burnt alive.'

But the revolution that Leonardo da Vinci and Copernicus began went on. *Per aspera ad astra*, Galileo Galilei inscribed on his banner (Through thorns to the stars). The torch was taken up and passed on. His comrades-in-arms who continued his cause were many—Johann Kepler, Francis Bacon, René Descartes, Pierre de Fermat, Robert Boyle, Robert Hooke, and others to, finally, Isaac Newton and Christian Huygheus. And if the cornerstone of present-day science was laid in Leonardo's time, and the foundations in Galileo's, the building itself was erected by Newton. The great work has continued for more than 200 years. It was done, however, not solely by great scientists. The legion of investigators had been growing all the time and no longer consisted, as before, of isolated

figures and rare groups, sporadically forming and breaking up. Scientists, professional and amateur, now formed a stable social stratum that was continuously growing. They united in societies along the lines of the craft and merchant guilds. The first corporation of this kind came into being in Italy, the Accademia Secretorum Naturae (Academy of the Secrets of Nature), founded in Naples in 1560. In 1660 the Royal Society was founded in England, in 1668 the Académie des Sciences in France, in 1700 an Academy in Prussia, and in 1724 in Russia. And in addition to books, which appeared irregularly, periodical scientific publications began to be issued, the first *Le Journal des Savants* in Paris and the *Philosophical Transactions of the Royal Society* in London, both in 1665.

At this point we have an irresistable temptation to say something commendatory (probably for the thousand and first time) about the printed word.

The printing press, in successfully superseding the fastest copyist, did not simply do away with the slow and laborious copying of manuscripts by hand, but transformed books from expensive rarities into generally available things. By 1500, only half-a-century after the appearance of the first incunabuli coming off Gutenberg's press, book printing had penetrated twelve countries in Europe, everywhere promoting the spread of literacy.

Much broader sections of the populace than before were now drawn into the world of knowledge, including people (and this is very important) directly occupied with production and well acquainted with it. In pondering over its needs and requirements they could henceforth turn to the store of world experience.

A veritable revolution occurred that has even been compared with the revolution brought about by mastery of the working of iron. Just as iron, being cheaper

than bronze, at once democratized the instruments of manual labour and made better metal tools available to working people, so printing did the same with the subjects of brain work and sources of information. It became a vital factor accelerating scientific and technical progress that still operates.

From then on one of the main obstacles preventing development of the human gift for invention and discovery was removed (no nation, of course, lacks talent; and if their talents lie hidden in the ground, it is primarily because of unfavourable social conditions). The wall separating science and production was breached and the gap closed between the theoretical knowledge of the educated man and the practical know-how of the worker, like the skills of the artisan, who, however fine a master of his trade, was unable to advance it further for lack of knowledge. That knowledge could now be drawn on for self-education and improvement.

Specialized periodicals acquired special significance in that, of course—newspapers and journals that informed the inquiring reader of new problems, inquiries, and solutions in the field interesting him. They informed him, not sporadically, from time to time, as with books, but regularly, with a definite rhythm according to announced time schedules.

The pulse of world science began to be really tangible; each and every one could take it. And it was not at all necessary to be present at the sessions of scientific societies in order to keep informed. Science gradually found its way out of studies and laboratories, dropping in more and more frequently at mines and workshops.

Much has changed since then, of course, both qualitatively and quantitatively. Nevertheless we can say that, in the course of the last three hundred years or

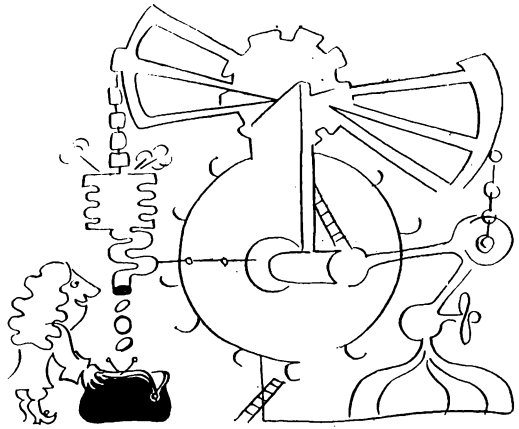
so, science has only been following the guiding principles that were laid down in the seventeenth century.

The main thing about its development in the 'post-Galileo' stage is the following: whereas, earlier, during the whole preceding period, we observed the evolution of science as such, from now on we see something else, its establishment as a direct productive force.

Capitalism (and its biography really begins then in the seventeenth century with the English bourgeois revolution) 'puts the natural sciences into service in the direct process of production for the first time', Marx wrote in notes made for *Capital* in 1863; on the other hand 'the development of production provides means for the theoretical mastery of nature.'

But why is that so? Why was it capitalism that first did it? Lenin explained it in his *Development of Capitalism in Russia* in this way, that 'large-scale machine industry alone introduces a radical change, throws manual skill overboard, transforms production on new, rational principles, and systematically applies science to production.'

As a matter of fact, it isn't everything to acquire machines, for they are only one link in the technological chain. Even though it is the main, most important link, it is not the only one, being powerless without the others, and consequently, in general, is useless of and by itself. Before one can make a steam engine, say, the heart of a factory organism, it is necessary to think out the whole complicated (and costly) complex of equipment, appliances, and communications, down to the smallest details, so that all its parts constitute a harmonious whole in which there is nothing superfluous. And that simply cannot be done without science, which helps get the maximum effect with the minimum means; only science makes it possible to go on and on improving the technology of production.



In the conditions of free competition any inefficient enterprise went to the wall, not just handicraft workshops but factories, too, if they had not installed the most advanced technology and equipment. The hour of the machine had struck! Entrepreneurs introduce innovations and mechanize manual labour. Inventions and discoveries promising profit no longer lie buried but are drawn into the pursuit of gain; and the inventors become desirable fellow-travellers of capital.

But what about the scientists? From the middle of the seventeenth century there were more and more people among them who turned toward production. More and more they concerned themselves with its pressing problems, not only indirectly, on a general theoretical level, but directly, working on concrete tasks posed by industry. Some of the 'applied' scientists, who had a practical bent, themselves became successful businessmen. James Watt, for example, was not only an inventor but also an industrialist.

Seeing how incorporeal ideas, to their complete

amazement, were materialized as gold, the bourgeoisie gazed with diminishing haughtiness and increasing favour on these 'eccentrics' and 'unworldly' people who slogged away at books or instruments not for the sake of future gains but simply 'for love of art'. But they were still not in a position to evaluate the significance of inquiries that did not produce immediate returns. Such quests seemed senseless; but let them get on with their witchcraft; it might produce something.

It never occurred to the businessman that his successors, the capitalists of the twentieth century, would be spending millions on such research. He was on his own, and scientists were on theirs. He had nothing against them, of course, on the contrary, he was all for science (or rather, for its fruits, which he reaped free of charge). But to finance it in the hope of getting results of some sort? Not on your life! A bird in the hand was worth two in the bush.

The colossal productive power of science was not recognized immediately in capitalist society. Far from it! 'What has the economist to do with the spirit of invention? Land, capital and labour are for him the conditions of wealth, and he requires no more. Science is no concern of his. What does it matter to him that he has received its gifts through Bertholet, Davy, Liebig, Watt, Cartwright, etc.—gifts which have benefited him and his production immeasurably? He does not know how to calculate such things; the advances of science go beyond his figures,' Engels wrote with bitter irony in his *Outlines of a Critique of Political Economy* about the short-sighted practical approach to science. 'And here it is certainly gratifying to know,' he said further, 'that the promotion of science also brings its material reward; to know that a single achievement of science like James Watt's steam-engine

has brought in more for the world in the first fifty years of its existence than the world has spent on the promotion of science since the beginning of time.'

'In a rational order which has gone beyond the division of interests as it is found with the economist,' Engels prophesied, 'the spiritual element certainly belongs among the elements of production and will find its place, too, in economics among the costs of production.' Prophetic words!

Soviet economists estimate that any research institute today has an economic effect equivalent to several large factories. Thus a research establishment with a scientific staff of 500 to 1000 persons can be looked upon as an enterprise with an annual output worth 25 to 50 million roubles, and so completely pays for itself, the social income from it being much bigger than the expenditure on it.

Bourgeois writers also recognize the leading role of science in present-day economic growth. The vice-president of the Martin Corporation in the United States, makers of the Titan intercontinental ballistic missile, said in connection with the setting up of a special research division of the corporation in 1955 that they considered knowledge *as such* should be a marketable product, a product that would be the most progressive, advanced one since it can only be imagined, as it is more abstract than real.

'The word "science" has as exciting a sound to entrepreneurs as "Klondyke" once had; and they are caught up in a "gold rush" of research and development.' So Prof. Volkov describes the hullabaloo about the 'ideas industry' in capitalist countries. 'Entrepreneurs are no longer satisfied with exploiting scientific results that are public property. They organize and finance it like the production of mass consumer goods. "Ideas factories" have appeared competing successfully with

factories making things. According to *World Science Review* in the past 25 years U.S. industry has obtained between twenty and fifty dollars profit for every dollar invested in research.'

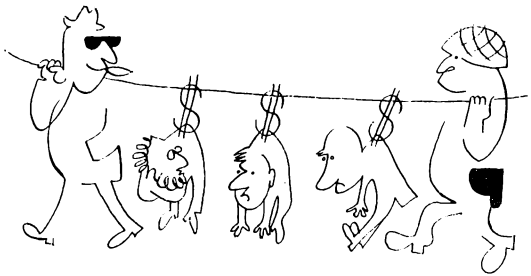
Yes, indeed, the social climate of science in the present century is quite different to what it was in the last century. Bourgeois society, it would seem, has so altered it that you couldn't imagine it better. So, could it be that in this field capitalism, at least in its present stage, has also become the rational system that Engels had in mind?

At first glance the tree of knowledge, having come with time into fabulously splendid flowering, and bearing in ever greater abundance, is injecting a magic elixir of eternal youth into the veins of the failing system in the United States and other developed countries. As if that were so!

Under private enterprise the fruits of science become an apple of contention between monopolies. And the creators of ideas become 'marketable goods' along with their ideas. Firms entice scientists from one another. The 'head hunters' spread their nets far and wide beyond the bounds of their own countries.

At the end of World War II, according to the American commentator Drew Pearson, all the rocket men of Germany, almost to the last man, fell into American hands. But they were 'trophies'. Now 'brain imports' have been put on a business basis.

A French sociologist has summed up this trend with Gallic wit. In olden times the most desirable victors' spoils were gold and slaves, but now they are know-how and scientists. But whereas, in the days of savagery the victors acted primitively, tolerating terrible brutality and straight pillage, in our enlightened age everything is done differently, and much more simply. Advertisements are placed in newspapers



abroad offering researchers a higher salary, a car, and a house, and an air ticket so as not to loiter on the way to the Transatlantic laboratory. To say 'all this is mine' has become the prerogative of gold; the sword is sheathed.

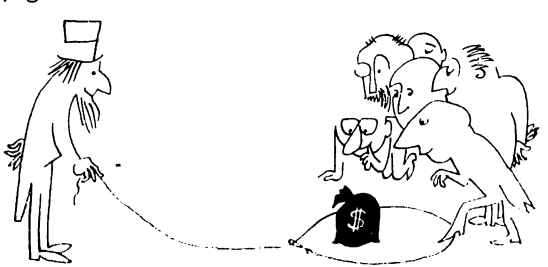
In the ten years between 1955 and 1965 alone (the beginning of the scientific and technical revolution) 53 000 scientists, mostly young and mainly West Europeans, settled in the USA, including 14 000 physicists and 30 000 engineers. What does such a sizeable flood of trained specialist immigrants (five thousand or more a year) signify? Here is how we calculate it. If you take it that the average university grants 500 degrees a year, it works out that a good ten of the world's colleges and universities are training all their graduates for a foreign uncle—Uncle Sam. And before entering university the students have spent a much longer time at their school desks. For ten years or more a country spends time and money on education that is only recouped by long years of work for the good of society. But here it is recouped not at home but in foreign parts!

The problem of the 'brain drain' also affects developing countries. For it is from them, from the 'third world' (especially Asia and Africa) where a national

intelligentsia is badly needed, that Western Europe is enticing 'golden fish', recruiting gifted specialists to offset the drain of its own brains across the Atlantic. And the gains go to those whose money bags are fattest. So there is good reason why every third Nobel Prize winner in the United States, and a sixth of the members of the National Academy of Sciences, is a native of another country, or a person who received his education outside the USA.

Perhaps ideal conditions for further scientific and technical progress are being created in the USA?

Nowhere else, certainly, have so many of the cream of the creative intelligentsia been gathered together from all over the world. Nowhere else, certainly, are scientists valued so highly! Truly valued—as commodities, and highly, but as capital that is put into intensive circulation to make maximum profit for the firm; and the firm, in trying to outdo its rivals, not only gets the fate of ideas into its clutches, buying them 'on the hoof', but also the freedom of their authors themselves, who count as its private property. Movable property, of course, but not so freely movable as to rub shoulders with anyone they wish; suppose they gave the firm's secrets away to a rival? Competition-phobia forces the monopolist to pigeonhole promising projects that he himself still hasn't the forces to implement; what, give them to someone else!



There it is, this 'paradise for scientists and science'. It needs no wise tempter like the serpent that tempted Adam and Eve with the fruits of the tree of knowledge of good and evil, to open people's eyes to the true state of affairs. What is good and what is bad here is obvious to the naked eye. Take the evidence of Norbert Wiener. 'I am particularly lucky,' he wrote in his autobiography *I am a Mathematician*, 'that it has not been necessary for me to remain for any considerable period a cog in a modern scientific factory, doing what I was told, accepting the problems given me by my superiors, and holding my own brain only *in commendam* as mediaeval vassal held his fiefs. If I had been born into this latter day feudal system of the intellect, it is my opinion that I would have amounted to little. From the bottom of my heart I pity the present generation of scientists, many of whom, whether they wish it or not, are doomed by the "spirit of the age" to be intellectual lackeys and clock punchers.'

Not everyone argues that way, of course. For many Paul Lafargue's prediction made at the beginning of the century proves to have been justified.

Men of science, he said, tried to avoid going into industry as hirelings, but they would be forced to do so and to put their brains at the disposal of ignorant employers. They would think themselves lucky, he added, to receive a modest recompense for discoveries that would bring in millions.

Nevertheless the omnipotence of Gold, presumptuously proclaiming 'I buy everything' over and over again, proves illusory when put to the test. Even American economists are beginning to understand that.

For example, J.K. Galbraith says in *The New Industrial Society*, that if only such 'technique' as picks and shovels is used to build a road, the builders can be hired the same day as the job begins. It would help,

if there were 'an industrial reserve army of the unemployed'. Or the labour force can be found by 'raiding the work force of another employer' in the ordinary way of market relations, or offering more pay.

But what happens when it comes to building a modern motorway with all its complicated civil engineering structures using machinery of every kind? The skilled personnel needed are not easily available in the right numbers and at the right time, for they cannot be kept ready at hand. And filthy lucre may not induce them to leave their comfortable niches for highly paid but short-term jobs. And what is one to say when it is a matter of developing whole branches of industry, like the ultramodern ones being born of the present scientific and technical revolution?

Galbraith was forced to recognize that when it is a matter of 'inertial systems engineers, digital circuit design specialists, superconductivity research specialists, aeroelasticity investigators and radio test and evaluation engineers as also for titanium alloys in comparison with steel, and space vehicles as compared with motorcycles, the market is greatly less dependable. Need must be elaborately anticipated and arranged.' Let us add: it must be anticipated and planned on the scale of the economy as a whole for many years, even for decades, ahead.

So we come back once more to the problem of national planning, a problem that is the stumbling block for a society based on market forces.

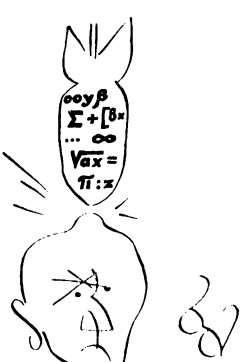
Even in the sphere of education, in which interference 'from above' is more or less tolerated on a quite wide scale, state regulation runs into insuperable obstacles arising from the very nature of the capitalist system.

In an article in *Pravda* some time ago, Prof. N.N. Inozemtsev, Member of the USSR Academy of Sciences

and Director of the Academy's Institute of World Economics and International Relations, described the present situation as follows: 'The scientific and technical revolution which, in its first stage (linked with the use and rapid development of several new branches of industry), brought about a certain reduction of unemployment, caused a sharpening of the employment problem in the second half of the Sixties. And it particularly affects young people, who lack the training and skills required, and older workers who are unable to stand the high work tempos or whose trade is old-fashioned and has been superseded.

'An acute contradiction is created between the rapidly growing demands posed by scientific and technical progress as regards the skill and education of workers, and the established system of general education and trade training in bourgeois countries and the social and class barriers inherent in this system.'

There is no reason to question that this bald statement, stated without supporting figures, is the result of a careful, thorough analysis of the relevant statistics.



The problem of scientific personnel is becoming very acute in our times. The number of scientific workers in the world is now close to four million, which is many more than the number in the whole period from the first wheel to the first artificial earth satellite, from the cave campfire to the atomic pile. A more or less accurate calculation can be made for the last 300 to 350 years. What do you think is the proportion of the scientists who are working and in good health today in the total for that period? Nine-tenths!

That's all very fine, of course, but the contingent of scientists is multiplying much faster than humanity as a whole. If it continued at the present rate, in 80 years time, i.e. about the year 2050, the whole adult population of our planet would have to be engaged in research, giving up all other jobs. Some reader may well ask: 'And why not?'

Well, in principle, it is possible, but only in a rational system in which the difference between work by hand and by brain has been abolished, when production (especially agriculture) has become fully automated and highly productive. But most countries of the 'third world' have not even reached the stage of machine-factory production. Heavy manual labour has not been eliminated. And what about the food problem? It is quite on the cards that it will remain Problem No. One for millions of people for some decades to come. How can a man think of lofty matters when he hasn't a crust of bread!

Clearly, the progress of science is closely linked with social progress.

But the present boom in the numbers of scientific personnel will not go on forever. In any case it must slow down. Imagine that all the inhabitants of the Earth, big and small, wanted to become scientists, and did so; the rate of growth then simply could not

exceed the rate of growth of the population of the world. But if that happened wouldn't it put the brakes on scientific progress sooner or later? Though in time scientists may be reinforced by electronic colleagues, by a vast staff of robots. But that is a matter of the distant future. What about now?

The technical staffs of research institutes and laboratories are now proliferating faster than the research staff proper, that is to say those who are directly engaged in scientific quests. And there's the snag; they have less and less time for quests! They are now spending more and more time on work that is far from creative, digging like archaeologists into tumuli of books for buried information.

Once upon a time a scientist could easily look through all the specialized journals. There were not many of them then—about 100 in 1800. But in 1950 there were already 100 000, and now there are more than 200 000 (with nearly five million articles!). Today's chemist, even if he had nothing else to do except to pore over the literature in his subject, and could skim through 200 papers a day without rest or a break, and without taking a day off or a holiday, could not, just the same, get through more than a tenth of the information published by his fellow chemists. The same goes for biologists, physicists, astronomers, and mathematicians. The quantity of printed matter produced per reader (i.e. per scientist) is so great that the daily dollop is some ten times as big as the book you are holding and reading now. Imagine how that exceeds the normal human capacity to digest mental food. But the scientist needs to know everything relating to his work. Won't the efficiency of the ideas industry begin to fall then in the next few years?

Suppose, however, that it proves possible to automate the search for the required information and to

alter it so much that it becomes quick and easy. All the same the problem would still be with us; the human brain is threatened with a catastrophic collision with 'megabit bombs' (as Stanislav Lem calls them from 'mega', a million, and 'bit', a unit of information). The volume of scientific knowledge today is already measured in thousands of millions of megabits, and goes on increasing at a rate of 3 per cent per annum.

In order to cover the syllabus of secondary school and then of higher education it now takes approximately fifteen years. And then the graduate usually needs another year or two to get into the swing of things before he embarks on independent research. But the volume of knowledge is growing and growing. Won't the length of time spent within the walls of schools and colleges get longer too? Won't universities soon be turning out grey-haired, balding 'young scientists'?

But in mathematics, physics, and certain other very important fields of science, the 'golden age' of creative productivity is anything but 'venerable', meaning by that a high percentage of silver in the hair. The critical age is between twenty and thirty, occasionally up to forty. Evariste Galois (1811-1832), for example, was still a youth when he worked out his theory of groups which subsequently provided the key to almost all current algebra and geometry. (He was killed in a duel at twenty-one.)

Albert Einstein, Niels Bohr, and Paul Dirac made their outstanding discoveries at twenty-six or seven. Karl Linnaeus published his famous *System of Nature* at twenty-eight. James Watt was not thirty when he invented his steam engine. Dmitry Mendeleev had just turned thirty-five when he published his classification of the elements. Isaac Newton had laid the foundations of physics long before he was forty. The genius

who does anything comparable with the main achievement of his life after forty or forty-five is rare.

So we have to train specialists for independent work as quickly as possible. It is desirable if they can start as early as possible, preferably before twenty. By that time, however, he or she must already have a fully adequate store of knowledge; but how—if the volume of scientific information is snowballing?

The problem of intensifying work by brain certainly cannot be dismissed as futile. But what to do about it?

Some people talk about the possibility of increasing the number of gifted people simply by copying them, by some sort of replication. Imagine, for example, that a single cell taken from your body and cultured in a natural (or artificial) medium in a 'biological incubator' grew into your twin, completely reproducing you in looks and talents. Both of you would seem identical twins except for a difference in age of ten or twenty years. That way some rare talent could be made immortal; its bearers, of course, would die sooner or later, but their genius would be reborn each time in a younger *alter ego* ('other self'). But that, alas, is still only a pipedream.

Others recall eugenics, of sorry fame. In his contribution to *The Science of Science*, a paper on 'The Proper Social Application of the Knowledge of Human Genetics', the late Prof. J.B.S. Haldane, F.R.S., discussed the idea of improving the human species. 'We could,' he wrote, 'reduce the frequency of congenitally sub-normal babies, although probably not more than by half. We could not ... greatly increase the number of babies with superior endowment.

'A vast improvement in social structure is needed before we can think, with any hope of success, of what innate human capacities are needed in its components.'

Commenting on Haldane's article in the foreword to the Russian edition of *The Science of Science*, Prof. V. N. Stoletov, now President of the USSR Academy of Educational Sciences, himself a biologist, remarked: 'The author was a progressive-minded scientist, a Marxist and consistent antifascist. He well knew the harm the Nazis had caused humanity, and that they had employed individual half-baked hypotheses from genetics for their brutal ends. That was the fault of the nature of fascism and not of science. One would be stupid to convince himself and others that, because the fascists employed anthropogenetics, we should reject any need to develop this branch of biology. . . . On the contrary, research into human genetics can yield much that is useful in fighting for the health and all-round development of man. It would be a great mistake to look for solutions to social problems in anthropogenetics, but it would be no less a mistake to reject this science as a means of working for human health in conditions of an improved social structure.'

So we are brought back again to the need for social transformation.

Another contributor to *The Science of Science*, Derek de Solla Price, says in his book *Big Science, Little Science* that not everyone can be a scientist (even of the lowest qualifications), but only 6 to 8 per cent of the population. Science, he argues, is getting close to senility and its human resources will soon be exhausted. Prof. Stoletov disputes his conclusions and adduces the fact that a good half of humanity is still illiterate. That being so, it lacks knowledge and is not even in a position to make use of it, let alone increase it. In those circumstances he thinks there are no grounds for arguing about the percentage of people capable of carrying out research.

The human resources of science, on the contrary, can

and should be expanded. Prof. Stoletov says that inquiries in various directions can help resolve this problem. 'Some of them (like anthropogenetics) can only exert a positive effect in the future, but others can operate sooner. One of these is to provide the youth with universal compulsory secondary education and to improve the system of special education (both secondary and higher).' Because the more education is improved the higher will the proportion of humanity that will prove useful for science.

So the fate of scientific progress depends primarily on social progress. And if Derek Price is right in part in drawing attention to the approaching flagging of science and fall in its standards, his point is not a general one but applies to social conditions.

'Although Price bases himself on facts from the history of science,' concludes Prof. Stoletov, 'in fact his thinking is anti-historical. This paradox is an inevitable consequence of using the abstract-historical approach, which frequently leads to subjective conclusions. Price looks on history in such a way that all the conditions for the development of science are taken as invariables, namely the economic structure of the world, social systems, standard of education, the accessibility of science to the mass of the people, and so on. He takes all these as constants. And that methodological error underlies the failure of all his conclusions and forecasts. . . . In analysing the future of science one must employ a *concrete-historical* approach, that prevents one from overstepping the bounds of the particular social system.'

To overcome the limitations of bourgeois sociology of science one needs to employ Marxist-Leninist theory. A concrete, historical example that confirms its correctness is the more than half-a-century's experience of the first socialist state in the world.

Science in the Republic of Labour

Predicting unprecedented scientific, technical, and social progress in the communist future, Frederick Engels said in his *Dialectics of Nature*: 'Only conscious organization of social production, in which production and distribution are carried on in a planned way, can lift mankind above the rest of the animal world as regards the social aspect, in the same way that production in general has done this for men in their aspect as species. Historical evolution makes such an organization daily more indispensable, but also with every day more possible. From it will date a new epoch of history, in which mankind itself, and with mankind all branches of its activity, and especially natural science, will experience an advance that will put everything preceding it in the deepest shade.'

The road to this new historical epoch was taken by the first socialist state in the world, which began, for the first time, consciously to plan its development on a national scale and demonstrated its ability to guide scientific and technical progress effectively as well as social and economic advance.

It has now acquired rich experience of planning science. An idea of how much can be got from study of the USSR Academy of Sciences, which has been called the 'General Staff of Soviet Science'.

In 1927 the first post-Revolutionary charter of the Academy was promulgated. It replaced the old one granted back in 1836. The new charter was a declaration of the principles of planning in research.

Before the Revolution, we should note, scientific work in Russia was never planned. The staff of the Academy, of course, were not used to such an approach to their work, and some considered it an interference with the 'free flight of creative thought' and its inner logic that restricted it to the framework of some 'task' or 'assignment'.

Such misgivings were generated by the anarchistic tradition built up during the pre-Revolutionary period when researchers worked spontaneously, in seclusion, and isolated, encountering no special encouragement from the Czarist government.

The Soviet state, unlike others, was interested in the progress of science and technology. It was not solely or so much that it experienced incredible economic difficulties in the first post-Revolutionary years arising from the imperialist war, intervention, and the suppression of White Guard rebellions. Bourgeois landlord Russia could also, sooner or later, have coped with the disruption but it would never have reached the level to which regenerated Russia—Soviet and socialist—was raised.

When real people's power triumphed, under the leadership of the Communist Party, and the building of socialism began, new perspectives were opened for scientific and technical progress.

'In the old days,' Lenin said at the Third Congress of Soviets in January 1918, 'human genius, the brain



of man, created only to give some the benefits of technology and culture, and to deprive others of the bare necessities, education and development. From now on all the marvels of science and the gains of culture belong to the nation as a whole, and never again will man's brain and human genius be used for oppression and exploitation.'

But it began to happen in most difficult circumstances.

What heritage remained from capitalism in the Soviet Union? Here are the 'cultural heights' to which capitalists had raised Russia. 'There is no other country so barbarous,' Lenin wrote in 1912 about the policy of the Czarist Ministry of Education, 'and in which the masses of the people are *robbed* to such an extent of education, light and knowledge—no other such country has remained in Europe; Russia is the exception. . .' But after the Revolution, when it became possible to co-ordinate the efforts of all the people on a national scale, it also became really possible, as it had not been for the old system, to overcome Russia's age-old backwardness in the shortest possible time.

The new road for resolving perennial problems, that of planned direction of scientific and technological progress and not simply of economic and social

advance, was blazed by the Communist Party in the very first months of the Soviet state when, in April 1918, Lenin drew up his 'Draft Plan for Scientific and Technical Work'. This document envisaged drawing scientists as quickly and as actively as possible into working out a programme of social and economic and scientific-technical progress.

Could the Academy of Sciences stand aside from these pressing national problems?

No one, of course, either then or later when its new charter was granted, ordered scientists 'to discover this or that in such and such a time'. But in the situation when scientists were few in number, it was suggested that they should make a considered reconnaissance along previously marked trails and not fritter their efforts away on innumerable themes and topics but concentrate them along the line of the main blow, in the most promising directions. The strategy of this offensive was to be planned by the Academy itself, by analysing the existing situation, forecasting the future, correlating its possibilities with the needs of the country, co-ordinating the individual plans of its members and staff and institutions on a national scale.

This approach—planned and programmed—fully justified itself. Its effectiveness, and above all its necessity, have long ceased to be questioned by anyone anywhere, even in the West, and even by our most carping critics. Attempts to apply it along our lines—within the bounds of their possibilities, of course—were also made in other countries (recall, for example, the forced pace of atomic and space research in the United States through multi-billion dollar projects entailing a long-term look—years, even decades, ahead). But the counterposing of plans to *laissez-faire*, of order to anarchy, is only really possible under a socialist system.

In 1930 the General Assembly of the USSR Academy of Sciences adopted a general programme of work, singling out three main directions, namely general theoretical research of a long-term character, research meeting immediate practical needs of national reconstruction, and finally all-round promotion of the cultural transformation of the country, especially among the national minorities of its periphery. And in 1932 the Academy adopted its own five-year plan.

Prof. A.F. Joffe, member of the Academy, recalled those days as follows. 'We saw with our own eyes the power of science when directed to the good of humanity. Science is not an amusement or hobby, not simply satisfaction of the mind's need to know and understand. Science is an invaluable tool for changing life.'

Our Soviet advances would have been even more remarkable if it hadn't been for the war launched against us. On the other hand, if it hadn't been for our achievements, what might not have happened?

'If Russia had remained a monarchy or had become a republic with a capitalist system, and had developed as slowly as before, it would not have withstood the onslaught of the fascist armies,' said Prof. V. N. Obruchev, member of the Academy, at its jubilee session in connection with the twenty-fifth anniversary of the road taken by the Land of Soviets. 'Germany would quickly have conquered all Europe from the Urals and the Caucasus and, exploiting its natural resources, would have enslaved all the nations of Europe and the world.

'In the distant future historians will note these twenty-five years of the existence of the first socialist Soviet State as a period of particularly rapid development of scientific research, freed from the shackles of the old society.'

The celebration of Victory in 1945 co-incided with

the 220th anniversary of the Academy. Prof. A. Paul, a member of the American delegation, said then that they were astonished by our intellectual vitality and the speed and determination with which we were healing the terrible wounds caused by the war.

While helping the economy to cope with its urgent practical tasks, the Academy had to keep up with world scientific progress and carry out long-term research anticipating practical application; and in this the experience of planning gained before the war proved useful.

In 1946 the General Assembly of the USSR Academy of Sciences adopted a new five-year plan for its work that included 633 problems and embracing nuclear engineering, space research, and radio-electronics.

In the post-war years new branches of the Academy and research centres were founded, and by 1961 all the fifteen Union Republics of the USSR had their own national academies.

The policy of extending the network of scientific centres adopted back in the Twenties and Thirties had paid off. Prof. A.N. Nesmeyanov, then President of the Academy, referring to the example of its West Siberian branch, set up during the war, said: 'The research into mining carried out at this branch has yielded results of such importance for the coal industry that the annual saving from their application has covered all our expenditure on our branches with interest.'

The major organizational measure of the Academy since the war has been the setting up of a Siberian Department (in 1957) under whose aegis come all the Academy's branches east of the Urals.

In 1917 the Academy had one research institute, five laboratories, six museums, a library, archives, and a printing press. By the fiftieth anniversary of the Revolution the number of Soviet scientific institutions

exceeded 4700 (more than 200 of which belonged to the Academy).

As for scientific workers, their numbers increased more than 250-fold in those fifty years (1917-67). In 1970 there were 930 000 (a quarter of the world's total), of whom 240 000 had advanced degrees. But it is not a matter of degrees, of course. The qualifications and achievements of Soviet scientists have received world recognition, which can easily be illustrated from any branch of science or technology. Here is one instance that will give you an idea of how our scientific younger generation is growing.

Young Soviet mathematicians, the President of the International Mathematical Association, Henri Cartan, declared in 1966, without any doubt deserved the highest praise and had a great future.

Some readers, however, may object to that example, for where would you expect youth to succeed if not in mathematics?

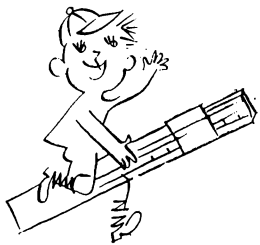
All right then, that is so; but it is worth remembering that for mathematical capabilities to flourish (and not every one, you will agree, has them), a social climate favouring their flowering is required. And that is why our example is particularly illuminating.

In 1967 two Moscow scientists, Sergei Novikov and Yuri Manin (both of the Steklov Mathematical Institute), were awarded the Lenin Prize. The first-named, a Corresponding Member of the Academy, was then only twenty-eight, and the second, a Doctor of Sciences, thirty. And not long before that, in 1965, Vladimir Arnold, a twenty-eight-year-old professor of Moscow University, also received a Lenin Prize.

It was this contrast, such youth and such mature work, that several commentators remarked on.

Attention was also drawn to the complexity of the problems resting on the shoulders of these young prize-





winners—problems that seem quite beyond the powers of comprehension of 'simple mortals', and, as they say, rather out of the ordinary. Scientists are taking roads where it is far more difficult to hope for public recognition than, say, in the realm of technical invention.

But our contemporaries are no different in this respect than their predecessors, for example, in the last century, in Lobachevsky's time. But the advances of young Soviet mathematicians really reflect what is unusual about this century compared with the nineteenth.

In the first place, however scarce abilities are, possibilities for their development must still be provided for the individual by society.

Once, recalling the scientists who had made Russian mathematics world famous, S.I. Vavilov, the third President of the USSR Academy, named the geometrician N.I. Lobachevsky (1793-1856), and the analysts M.V. Ostrogradsky, S.V. Kovalevskaya, and P.L. Chebyshev.

Lobachevsky's outstanding ability showed itself

early. At 14 he entered Kazan University and at 18 received his Master's degree *cum laude*. At 23 he was already a professor and at 32 rector of the University. In a certain sense his career was ordinary, for youth is the golden age for the creative scientist. But if we consider his scientific career it was quite untypical of Czarist Russia, where discovery of mathematical talent (of which the Russian people have never been short) always remained a matter of chance. That is how it was in the nineteenth century and at the beginning of the twentieth.

Not long before the October Revolution of 1917 Petersburg and Moscow Universities and another two or three higher educational institutions trained several dozen mathematicians a year (a hundred or more times fewer than now); and that was in a country with a population of 150 million. And not all the graduates by any means devoted themselves to a scientific career.

'Scientific research became the profession of a very few persons who remained in the universities, because the number of staff appointments was very small,' Vavilov said. 'In only a few cases did scientists get a chance to found a school and find disciples and assistants. The best work of Russian scientists often ended with them and was forgotten. The main reason for that state of affairs was that the Czarist government did not understand the role of Russian science, ignored it, and preferred, when necessary, to import scientific results and technology from abroad.'

The fate of Lobachevsky himself can serve as an example. The outward prosperity and brilliance of his career conceal a real drama; his ideas did not find sympathy or understanding let alone recognition. The 'Kazan madman' they called him, little suspecting that soon the world would call him the 'Coperni-

out of geometry'. They hounded him in print and out. In 1846 he was dismissed as rector, in spite of the intercession of the University Council. And in 1847 he was deprived of his professorship and released from all his duties at the University. The sacking bore all the marks of gross administrative discrimination bordering on direct insult. Lobachevsky was not the only victim. The atmosphere that reigned in pre-Revolutionary science can be judged from the letter sent by the great physicist Prof. P. N. Lebedev to Prof. A. V. Golitsyn, member of the Academy, in 1905. 'All my work as a cultivator of science in our dear country seems to me so much vulgar fiddling about,' he wrote. 'I feel that as a scientist I am irretrievably lost; the conditions around us are a continuous overwhelming nightmare. If they get round in the Academy to discussing the prosperity of science in Russia, tell them in the name of this miserable Moscow professor that there is neither prosperity nor science, in fact, nothing.'

In 1911 the author of those lines joined the leading scholars of Moscow University in submitting their resignations as a protest against the tyrannical ways of the Czarist Minister of Education. Together with other prominent scientists, also victims of persecution, Lebedev was forced to leave the University. And although well-wishers gave him refuge and put a basement at his disposal, and made private gifts to endow him, he no longer had the necessary conditions for successfully continuing his work. Suffering terribly from the ill-starred fate of the work to which he had devoted twenty-five years of his life, the forty-five-year-old professor took to his bed and never rose again. He died in the spring of 1912 and did not survive to see his triumph in Stockholm (Lebedev's name was put forward for the Nobel Prize, but it is not awarded posthumously).

Through his untimely death, or rather through being driven to the grave at the height of his creative powers, Lebedev did not see post-Revolutionary Russia, in which the dreams of A.M. Butlerov, another great Russian scientist (chemist) became reality. 'Science,' Butlerov said, 'only exists easily and freely where it is enveloped in the full sympathy of society. Science can rely on this sympathy when society is sufficiently close to it in spirit. Society then does not consider its interests to be alien and recognizes that science is its best source of strength.'

Scientific progress, of course, did not stand still in Russia, though it moved forward mainly through the personal initiative of scientists who often could only rely on their private resources or on the patronage of some independent Maecenas.

'What was new in the position of science under Soviet power,' Prof. Vavilov wrote, 'showed primarily in the radical change in the attitude of the new government to the role of research in the life of the nation. Science ceased to be a private or "philanthropic" social undertaking. It more and more clearly acquired the significance of a very important state affair to which the Soviet Government and the Communist Party paid special attention.'

Here is what he said, in particular, about mathematics. 'Never has it attained such breadth, variety, and depth as in Soviet times.'

Among the galaxy of brilliant Soviet mathematicians named by Vavilov was Sergei Sobolev. At twenty-five he was elected by his colleagues a Corresponding Member of the Academy of Sciences, and then, five years later, in 1939, a full member. At the time of writing he is head of the Institute of Mathematics in Akademgorod (in Novosibirsk) and has disciples and followers,



several of whom have already become venerable scientists and teachers.

Together with M.A. Lavrentiev, the chairman of the Siberian Department of the Academy, and also a mathematician, Sobolev is an enthusiast of new teaching methods aimed at active search for talent, and those in whom it shows up very early in life, and at creating the most favourable conditions for their education.

Their initiative has found understanding and support from the state. For many years, now, an annual national-wide Physics and Mathematics Olympiad has been held in the USSR. It helps bring to light the aptitudes and abilities of future university entrants. Boys and girls who particularly distinguish themselves are given the opportunity to transfer from their ordinary secondary school to one that specializes in mathematics and physics, where they will receive more fundamental training in these subjects. Such schools

have been set up in Moscow, Leningrad, Novosibirsk, Kiev, Tbilisi, Dushanbe, and other cities.

That is what conditions are like when a country goes in for early mass discovery of mathematical gifts, and their discovery, in the words of the song, 'at the hazy dawn of youth' more and more becomes the rule. And if there is really anything astonishing about it, it is only because it is the manifestation of these talents that is extraordinary, especially with such bright talents as those of Novikov, Manin and Arnold.

These three young men, it is true, came to mathematics in the Fifties before there were yet annual nation-wide Olympiads or specialized secondary schools with a mathematic and physical bias. But that did not signify, by any means, that no attention was being paid to the mass discovery of mathematical gifts. It was being done, and very actively, though on a smaller scale. Schools had their physics and mathematics circles. And even before World War II it was already the established custom to hold city-wide Olympiads. It was in one of these city competitions that the Moscow schoolboy Vladimir Arnold came to light. Yuri Manin, too, was spotted while still at school, and in his student years was already doing independent research.

As for Sergei Novikov, the circumstances of his education would seem at first glance to be quite exceptional. His father, P.S. Novikov, was a member of the Academy, one of our leading authorities on mathematical logic, and a winner of the Lenin Prize in 1958. His mother was also a mathematician, a D.Sc., working on the theory of sets.

There is no doubt that family circumstances tended to rouse what is called 'a taste for mathematics' in the boy in childhood. But the son, absorbed by topology, found his own road, which did not lie in the di-

rection in which either of his parents specialized. Such a choice, and such rapid progress along this road, was unthinkable, of course, without the systematic training received in Soviet schools, first in secondary school and then in university. And his teachers undoubtedly had a great influence in forming Novikov Junior's interests.

Now, when the intake of Soviet mathematical departments and faculties is expanding every year, mathematics is receiving more numerous and promising reinforcements, which is a sure pledge of further significant progress.

But a few words about the paths mathematics is taking.

Let us recall the fate of Lobachevsky. Unrecognized in his homeland, harassed by chiefs and colleagues, and blind through overwork, he dictated his *Pangeometry*, hoping posterity would understand it.

Topology, to which Sergei Novikov's work was considered the major contribution of the last decade, is a no less 'mad' (pardon the expression) field of mathematics (popularizers call it 'the geometry of rubber shapes'). But however that may be, and however useless his work may seem to the uninitiated, its real significance and its further fate could well be determined by experts. All such questions have been put by the Soviet state, since its first days, into the hands of scientists. And there is nothing astonishing in the fact that the first significant contribution to topology by Soviet scholars was made in the Twenties.

In 1932 the general duality principle was discovered by L.S. Pontryagin, now a member of the USSR Academy of Sciences. This was one of the most significant achievements of topology in this century—the result of the century! (We should add that Pontryagin is blind; an accident deprived him of his sight in child-

hood, but despite that he became a mathematician of world renown and the founder of a theoretical school.)

When Prof. Pontryagin suddenly turned in the Fifties to problems far removed from topology, to problems of the optimal control of technological processes (which are of top practical priority in our day), his switch to this new sphere of research was on his own initiative. As for the influence of society, it boiled down in this case to the public discussion of his work that preceded its honouring with a Lenin Prize in 1962.

Our requirements for mathematicians are now 90 per cent determined by the need for 'applied mathematicians', but that does not mean of course that purely theoretical studies not considered to have any direct application are gradually being brought to naught.

However far removed from practical application, however abstract and inaccessible the problems on which our scientists are engaged may seem to the uninitiated, they find full understanding and generous material support.

As for the state institutions that co-ordinate scientific activity over the whole country, they naturally base their recommendations on the views of scientists, so that individual and group programmes of research are determined in the last analysis by their authors and by leaders acquainted with their work.

The present age in Soviet science, when the state, vitally interested in its progress, is stimulating research in every way—both pure and applied—and when favourable conditions have been created for discovering and educating future Lobachevskies, is a time of new opportunities and new hopes for Soviet mathematics, the fame of which has already been increased by our scientists and will spread even more.

Not long before the venerable French mathematician Henri Cartan praised his young Soviet colleagues, after a visit to Moscow, the president of the American Economics Association, Theodore Schultz, also visited the USSR. On returning home he sounded the alarm. The USSR, he said, was succeeding in developing its human resources much better than the United States. Giving his impressions of our country, he said he was disturbed by the growth in the number of talented people.

But we may be excused if we put it more precisely. The peoples of our country have never lacked creative talents. If, in the past, they did not show to the same degree as now, it was because social conditions prevented it. In 1897, for example, when the first census of the population was taken in Russia, 72 persons in every 100 between the ages of nine and forty-nine, were illiterate. The position was particularly bad on the periphery of the Russian Empire. 'To wipe out illiteracy in Turkestan will take 4600 years,' the *Educational Herald* suggested in 1912, drawing a despondent picture of the lack of culture in these backward territories. In a few decades of Soviet power not only did the Kazakhs, and the Kirghiz, the Tajiks and the Turkmenians, and the other peoples of our country acquire schools (both secondary and higher) in which teaching was carried out in the native language, but they also developed national Academies of Sciences and numerous research institutions. The results were not slow to show.

In 1967 we graduated 200 000 engineers, or nearly five times as many as the United States (42 000). It is also worth comparing the number of qualified engineers employed in the two countries (in 1963): 1 420 000 in the USSR and 675 000 in the USA.

Expenditure on education, science, and culture ab-

sorbs about a sixth of the total budget of the USSR. In 1970 it was 24 700 million roubles out of a total of 152 300 million; and in 1971 was 25 800 million out of 160 600 million roubles, an increase of almost 4.5 per cent. It is worth noting, too, that the growth rate of our population is rather lower than that, so that broader opportunities to enjoy the right to education granted to all by the Constitution of the USSR are opening up before each new generation.

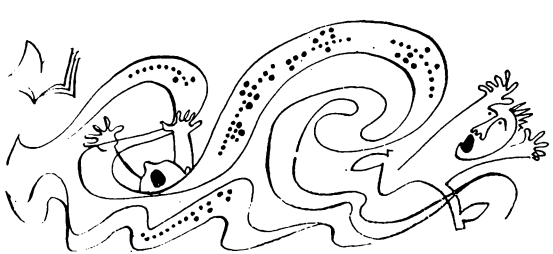
At the beginning of 1971 there were 44 million children studying in Soviet elementary and secondary schools, 2 500 000 young people attending vocational and trade training schools, and nine million students in technical colleges and universities. And to them should be added all the people taking special courses to raise their qualifications and improve their skill. In short, if you take the total for the whole country you get the imposing figure that one person in every three in the USSR is studying! Such provision of every possible form of education for a multimillion population is truly unprecedented in human history and has immense significance for society, scientific and technical progress, and the economic development of the country.

Back in the Twenties the economist S.G. Strumilin demonstrated that expenditure on school education gave a 27-fold return. 'Investment in people' is the most profitable way of using capital, a fact also recognized now by economists in other countries.

According to J.K. Galbraith every dollar spent on raising the educational level repays itself a hundredfold and increases the national income more than if it had been invested in railways, dams, or machine tools. The United States now spends about 9 per cent of its national income on education. Twenty years ago it was only about half that. In the USSR we

were then spending about 10 per cent of our national income on education and were the first to devote so much to that purpose. Only when the world's first atomic power station began working in the Soviet Land, and the first sputnik began orbiting the earth did consternation give way to scrutiny; Americans and West European experts set to work in all seriousness to examine the 'Russian miracle' and try to get down to its sources. Citing the instructive Soviet experience, American specialists recommended a reconsideration of the U.S. Budget, and in 1958 Congress passed a bill to increase appropriations for developing the education system.

The scientific and technical revolution, of course, is posing new problems, with its veritable flood of information. And scientists have concluded that the knowledge imparted in schools and universities is 'out of date' in something like ten years (once it used to last a whole human age!). So as not to fall behind the times every specialist and expert today needs to study unremittingly, and then learn his subject all over again! Can you imagine what it will be like tomorrow? It is not excluded that when today's boys and girls go to work they will need to take refresher courses so extensive as to be practically a



change of profession (and not once in their lifetime, either). That also applies to those who stick to their own chosen field. Because the very character of their work and their surroundings, whether laboratory, factory, or farm, even the home, will be altering rapidly out of all recognition. It will literally be 'live and learn'!

General education will become of special consequence in such conditions, as it will provide the cultural basis without which it will be impossible to increase and re-organize their store of knowledge and keep up with the seven-league strides of scientific and technical progress.

Research by Soviet sociologists has shown that a worker leaving school at seventeen (after finishing secondary school) masters new techniques and equipment about twice as quickly as someone who left school at fourteen, and there are five, even ten, times as many inventors and rationalizers among them. It can easily be imagined how useful it will be for the economy when universal compulsory education to seventeen is implemented during the current five-year plan (1971-5). It will not only benefit society as a whole but will also help every single individual. And more thorough training in a wide range of disciplines, from the natural sciences to the humanities, will encourage harmonious development of the intellect.

Very good. But the flood of new information will go on mounting. Will such an all-round grasp yield much of a return, or only a little of everything? For final-year pupils already have a twelve-hour day—six or seven hours of school lessons and as much homework—six days a week, Saturdays included. With what result? Scientists rightly criticize the secondary schools for cramming their pupils with nineteenth

century knowledge in many subjects (biology, chemistry, physics, and mathematics). And the syllabuses are so voluminous, as it is, that they simply cannot accommodate the very latest information. The textbooks are out-of-date before they are printed. Wouldn't it be better to go in for specialization as early as possible in a profession decided by tests of some sort?

It would be possible, of course, to set up special biology, chemistry, and economics schools, and so on, like our physics and mathematics schools. That would be one way of coping with the 'megabit bomb', but not the only way, and in any case, a very debatable way.

For doesn't early specialization sacrifice the intellectual potential of the human personality? Can those who are deeply versed in one subject at the expense of others really become valuable specialists in their chosen sphere of activity? Will they have a sufficiently broad outlook to be able to say the last word in science (which it is already difficult now to do without it) when the boundaries that used to divide the fields of knowledge are being ploughed up? Wouldn't neglect of the humanitarian disciplines have a negative effect on the moral qualities of the individual, on his higher creative capabilities that reveal themselves in imagination, fantasy, and intuition?

In discussing this difficulty Prof. Volkov had doubts about the expediency of differentiated education along specialist lines. He cited the experience of the United States where such a course was once quite popular but is now rejected (the foreign secretary of the U.S. Academy of Sciences, Harrison Brown, has declared, for example, that super-specialization is already dangerous and that what we need is what might be called a modern Man of the Renaissance).

What is the way out of the impasse, then? Answer: a radical overhaul of teaching.

Our present system of education, explains Volkov, was born during the Renaissance and took shape in Europe a little less than 300 years ago. Technology has passed through more than one revolution, but the school? The school has evolved only slowly and has lagged more and more behind life. Many of its founding methodological principles have been preserved in their pristine form. One of them was to teach everyone everything.

In those days these principles—they were crystallized under the reforming influence of the ideas of the great Czech teacher Jan Amos Komensky (Commenius) (1592-1670)—were undoubtedly progressive. Behind Komensky's idea of 'pansophia' can be felt the urge to break loose from the stuffy world of theological inertness and centuries of wasting the brains of scholars. It was a gigantic step forward. Pupils began to be considered as empty vessels to be filled to the brim with knowledge and the most diverse and varied facts and figures, including the latest discoveries of the naturalists of the day (luckily they were much fewer in number then than now).

But can today's teacher look on his pupils through the spectacles of his colleagues of the past? Is he really dealing with empty tanks for storing the spiritual wealth accumulated by our forefathers? Of course not. Pupils are not storage tanks but torches that must not simply be filled but even more must be lit!

One can understand why they thought of food for the mind not as creative fuel but rather as a simple filling of the memory. That corresponded completely with the spirit of science itself, which was still in the period of avid fact-finding and accumulation, and was only approaching the systematization of

things and phenomena. The indispensible attributes of the scholarly man, in Komensky's caustic characterization, were a brain fluid as quicksilver so as to mirror facts; an iron skull so that the head, stuffed with everything imaginable, would not split; and a pewter bottom enabling the owner to hatch out at least something.

In our day and age schools must, far more than at any time before, teach how to think.

'Factual knowledge is not only of short duration and useless in modern conditions but is also harmful,' Prof. Volkov remarks. 'It clogs the pupil's memory with unconnected information, facts, and figures, deprives it of flexibility and capacity for imagination and the grasping of a subject as a whole, and at the same time creates a false sense of superiority, of knowing it all and being well informed—that "erudition" that Heraclitus said did not teach to be wise.'

What is implied by the slogan 'teach to think'? Not, of course, a demand to 'do' more logic, forcing pupils to study it thoroughly almost from the first year of school. But from the first year teachers can and should inculcate something else, a spirit of real science and its ceaseless searching, which is not so much a system of knowledge as an industry of ideas, a continuously expanding branch of production that will require tens of millions of workers tomorrow.

A scientist, contrary to the root meaning of the word as 'learned', is not simply an educated person but rather one who has learned what is already known in order better to understand and in order to investigate what is still unknown or unexplored. He is an explorer, a scout, venturing into the unknown where he cannot expect prompting by anyone.

Soon science will need prodigious reinforcements.

And before tomorrow's recruits, today's schoolchildren, spreads a boundless field of knowledge where new vistas rise at every turning; plenty of work awaits them, a sea of unresolved problems. Future scientists, engineers, inventors, and innovators need not only to master knowledge in their youth but also to acquire habits of work by brain and techniques of research. They need the atmosphere of the laboratory and independent quests rather than that of a temple where boring sermons are preached.

But in accordance with the traditional method of teaching pupils are provided with everything and are spoon-fed from the very beginning; the fruits of the tree of knowledge are handed to them on a silver platter, and handed to them in the form of final results, although the researcher himself got them by the sweat of his brow, wandering in a labyrinth of ideas and doubts, not even sure that his search would be successful.

At first glance there is nothing wrong in that. Quite the contrary. It is simply wonderful if the conclusions that have taken years and years of unremitting effort to obtain can be memorized in five minutes. But to learn something off by heart does not mean at all to understand it. Real understanding comes rather from study, by going into something rather than by learning it by rote and by instruction.

What would happen if the classroom became a model of the situation in a laboratory? By setting up a 'problem situation', for example. By organizing teaching in such a way that pupils independently, as it were, repeat already made discoveries under the guidance, of course, of a teacher who always helps them get out of blind alleys?

It is more difficult, of course, but more fascinating. It rouses curiosity and brings out unexpected skills,



even in those who not so long ago had seemed not to be interested in anything much or were even lazy good-for-nothings. The main thing is that each and every pupil, while still at school, is initiated into the great mystery of scientific and technical creation. From childhood a person acquires a quite different attitude to spiritual values—an active conscious one (knowledge in order to reproduce it) instead of a dependent, consumer attitude (knowledge for sake of erudition).

Some advanced Soviet teachers go further and teach by the principles of invention. From analysis of the paths that have led to already known inventions and discoveries, it has been possible to formulate a series of recommendations on teaching method that encourage habits of engineering thinking and give intellectual 'efficiency'; and we already owe a host of patents and rationalization proposals to them.

Experience has shown that it is a mistake to consider that invention is the lot of a chosen few. Not at all. It is open to almost everyone, though it is not given to everyone to reach the heights to which Kulibin (the eighteenth century Russian inventor) or Edison rose. The USSR is one of the leading countries for the number of patents applied for. In 1969

there were around 120 000 applications, and in 1970 130 000. The number of patents granted is around 25 000 a year.

If the raising of the school-leaving age (even by one or two years) has given a noticeable increase in the creative activity of workers in present-day industry, what will be the effect of special courses in invention and rationalization? Their benefit is obvious. On the eve of the industrial revolution and in conditions of complex automation, the difference between work by hand and brain is being more and more obliterated. Workers need to think creatively as well as engineers and scientists.

The scientific and technical revolution, which is dictating the need for a revolution in the system of education, is presenting new opportunities as well as new demands. A great deal has been written about teaching machines, the 'cybernetic Pestalozzis',* whole complexes of equipment including computers, film projectors, television sets, and tape recorders. And there is much discussion of special syllabuses and courses that will intensify teaching and make it more effective, enabling the learner to master knowledge by means of machines, or without them from books, and adapting the process to the individual according to his or her capabilities and personal attributes.

It has been shown that with these new methods children can be taught to read at two years of age without special strain, and to write at three. Schoolchildren can master the rudiments of algebra and economics at seven, be introduced to the theory of

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* After Johann Heinrich Pestalozzi (b. 1746, d. 1827), the eminent Swiss teacher who developed methods of elementary teaching of one's native language, arithmetic, and geography.

relativity at nine and to differential and integral equations at eleven, while they can cope with complicated branches of mathematics and physics, chemistry and biology at university level (at least of the first year) in the senior classes at school.

A similar shift can be expected in higher education; and various projects for its reform in the USSR put forward by scientists and teachers are already being discussed. There are various schemes, but they are all alike as regards their main point, that the universities, like the secondary schools, must primarily teach how to think and how to apply the knowledge acquired creatively. Machines can also fill the memory vessel, which shows that here too there is no need for the special talents of a Commenius or a Pestalozzi. Where the teacher is needed is in lighting the lamp of reason!

In order to resolve the problems posed for the educational system by the scientific and technical revolution, innovations in teaching alone are not enough. Long range national planning is also required. If only because the period of teaching covers not one five year period but two or three. The contingent of future engineers and scientists being trained today must be suitable in quantity and quality for tomorrow's structure of the economy and its expected requirements for engineers and scientists of every speciality.

And hasn't the socialist state shown that it, and it alone, can best solve such problems?

Thus we have quite real possibilities of raising the 'creative efficiency' of graduates and school-leavers, and also of avoiding lengthening of the present period of education in spite of the burgeoning volume of knowledge. But what about the avalanche of scientific and technical information that future engineers

and scientists will not be able to avoid? What are we going to counterpose to the notorious 'megabit bomb'?

It is going to require a real revolution in the information industry, comparable with that brought about by the invention of printing.

The present scale of publishing is characterized by astronomical figures of titles and circulations that stir the uninitiated to enthusiastic admiration. But this continuously mounting output of the printing industry threatens people with another Deluge, though this time a dry flood of paper.

We are very impressed by the immense depositories of the printed word. But the spiritual values lodged in them are frequently as useless as talents hidden in the ground. The book fund of the Lenin Library in Moscow, for example, contains twenty or more million different books; almost half of them, however, lie there undisturbed and no one ever asks for them once. It is difficult to believe that there is not even one book among those ten million that no reader asks for that does not merit attention. The trouble is something else; the amount of print is so great that the flood overwhelms both bibliographers and readers. And the Lenin Library continues to fill; its shelves stretch for hundreds of miles and get longer every year.

Today, when the tempo of scientific and technical progress is unprecedentedly high, the time factor has become all important. Communications of the results of research can become out-of-date in a month or two. Obviously the space of time separating author and reader must be cut, but it has become longer than it used to be. In 1916 an article submitted to the *Journal of the Russian Physical Chemistry Society* appeared within three months; but in 1966 an article

submitted to the *Journal of Physical Chemistry* took eighteen months to appear.

The editor-in-chief of *High Energy Chemistry*, Prof. V. I. Goldansky, Corresponding Member of the USSR Academy, suggests a new approach, beginning at first with a few articles; in contrast to established practice, not to publish all the articles submitted but only to print short summaries of the most important new results (or perhaps, at most, condensed surveys of work on one theme or another). As for the full article ,it would be best to send it only to those who have ordered it specially after reading the abstract and desiring further details. Manuscripts can be reproduced quickly without printing in the number needed by readers. In that way it would be possible to shorten publication time, and reduce the size, and even the number, of journals.

But the greatest hopes, of course, are pinned on new techniques, above all on computers. Translation machines are being worked on, and automated information retrieval systems, and electronic encyclopaedias and reference books. Devices for microcopying are being developed; and there is talk of the advance of radio-electronics sooner or later leading to supercompact and at the same time supercapacious information stores. It is not improbable that some day the contents of a whole multi-volume encyclopaedia like the *Large Soviet Encyclopaedia* will be squeezed into a space the size of the head of a pin. And retranslator satellites like the Soviet *Molniya-1* (Lightning-1) series will be able to organize really 'lightning' exchange of information between research and teaching institutions, factories, and libraries on a continental or international scale. The celestial middleman will instantaneously transmit a blueprint or an article to any corner of the globe directly onto

the customer's screen, where necessary by-passing the publishing houses where manuscripts can lie about for weeks and months and become out of date before being published.

But all those are schemes and plans. It will not be easy or quick to implement them, and the problems they are concerned with are on the agenda now.

There are many of them, too, and their solution will not only require the mobilization of the intellectual forces of many research groups but will also call for more and more capital investment.

The investments are already vast, and growing all the time; and no society, however rich, has unlimited resources. The financial bodies of society are already faced with the problem how to utilize them more rationally, and will continue to be; and that goes for the USSR, too. With a planned economy solution of the problem is simplified, of course, but that doesn't mean that it can be done without an effort, even when it is not a matter of the budget as a whole but of only one of its items. Take appropriations for science. Even here, within the narrowest limits, for example, within the USSR Academy of Sciences, it is not easy to distribute the people's money over all the many items of expenditure so as to get the maximum effect.

For that reason, of course, the approach of the careful housewife who knows the value of every penny or kopeck is very important here; it is not a parochial approach, as when one's concern with one's own sowing in the field of knowledge seems of more consequence than anything else (from their ivory towers they cannot, of course, always see the wood for the trees), but is a truly national one, the one everyone is taught from childhood by socialist society. Can it really be foreign to Soviet scientists, even if, by the

very nature of their work, they are above 'all that pettifogging book-keeping'? Even there, it would seem, where it is not very opportune to put the question with the bluntness of an accountant: 'Look, your expenditure is rising, but what about your income?'

Let us take an example.

'Pyramids of the Nuclear Age' is how V.P. Kartsev entitled the chapter on particle accelerators in his *Treatise on Gravity*, an ode to 'the clearest memorials of our time, by which our descendants will judge the level of our culture'. His persistent theme, nevertheless, is just this 'accountant's approach'.

In 1967 a new accelerator was commissioned at Serpukhov. In accelerating particles to velocities close to the maximum possible limit, the speed of light, it can impart to them an energy of 70 000 million or more electron volts (or 70 gigaelectron volts, abbreviated 70 GeV). It was then the most powerful accelerator in the world. That is the point—'then'. A 200 GeV accelerator was being built in the USA; and a 1000 GeV machine was being designed in the USSR, and its scale model (17 metres in diameter) was already being tested.

The more powerful these very complicated machines are the more it costs to design and build them, and to use them. The first cyclotron (invented and built out of his own pocket by the American scientist Ernest Lawrence in 1930) had quite a low power, a little more than a thousandth of one GeV. It cost him altogether a thousand dollars. When the 33 GeV Brookhaven synchrophasotron was built, hundreds of firms were involved and it cost 34 million dollars, that is to say a million dollars per GeV.

The relation between cost and power, you see, remained about the same in the Sixties as it was in

the Thirties. But how capital expenditure had increased! Tens of thousands of times in thirty years. And if it goes on mounting at the same pace, in another decade or two it will lay a back-breaking financial burden on the shoulders even of the richest states. For 1000 GeV is far from the limit of desires of physicists! They would like to have microprojectiles at their disposal with energies of hundreds of thousands, or even millions of gigaelectron volts.

We cannot manage to do without accelerators, of course, but can't we do without the 'gigantomania' that costs fantastic sums of money?

Kartsev sees the way out in 'head-on-collision beams'. But perhaps it is better to let the man under whose aegis this method was developed have a word—Prof. G.I. Budker, Member of the USSR Academy, director of the Institute of Nuclear Physics of the Academy's Siberian Department, and Lenin Prize winner.

In an article in *Pravda* on the economics of the microworld Prof. Budker began with some amusing backchat he heard at a conference held twenty years ago in Dubna in connection with the commissioning of an accelerator there. One of those present suggested removing the railway siding that had been specially laid to bring in equipment (after the installation had been assembled, the spur was no longer needed). 'Why remove it?' one of the builders asked, quite astounded. 'What will you carry the products with then?'

All that accelerator has produced in the twenty years or more since is some photographs of nuclear reactions that could fit without much difficulty into a briefcase.

The job of accelerators is to produce scientific information, something quite ephemeral; but still,

was that question about their imponderable product so naive?

The luminous stream of particles shot into the air from an accelerator forms a brown cloud, probably because it produces a reaction that practically never happens in ordinary conditions, i.e. the combining of nitrogen and oxygen. The substance formed is a very valuable industrial raw material; and the day is not far off, scientists think, when goods trains will begin to carry tons and tons of economically valuable industrial by-products (nitrogen fertilizers for example) from the tall concrete blocks that house particle accelerators. For the present, however, well—Prof. Budker's Institute of Nuclear Physics has begun developing a new type of accelerator by an economic new method that will prove that fundamental science is capable of paying for itself.

The building of the accelerator is divided into several stages. First low-energy installations will be built. Then medium-energy ones. It might seem that each experimental model, having served its scientific purpose, should be scrapped; but not a bit of it! The small accelerator—which can be carried in an ordinary lorry—can yield as much radioactivity as tons of radium; and there is no need for thick biological shields because it is absolutely safe when it is switched off. The demand for such installations has proved to be quite big. In three years or so the Institute succeeded in signing contracts worth 15 million roubles, which was more than its grant from the budget of the Academy and gave it the possibility of financing fundamental research.

Thus expenditure on accelerators today can be covered by income from them; and the future prospects are quite extensive.

The amount of grain eaten by pests is immense

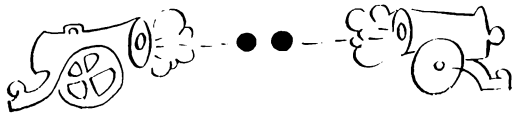
Its value on a world scale is probably more than the cost of the most powerful of existing accelerators. But it is possible to treat grain with doses of radiation that stop the pests from multiplying but are harmless to the grain itself.

A beam of fast particles is a wonderfully versatile worker! It can find minerals, treat diseases, sterilize drugs and medical supplies, preserve foodstuffs, purify effluent, check the quality of concrete or metals, examine thick layers of materials. But its main job is quite different, Prof. Budker says, and is to carry out basic research. No matter how valuable the practical return from accelerators, which will soon be measured in tens and hundreds of millions of roubles pure profit, their theoretical contribution to physics is more valuable still. Even when its whole product over twenty years is only a folder of photographs and calculations.

Physics needs more and more powerful accelerators. Then why the fuss about 'gigantomania'? For it is proving possible to build accelerators as strong as Hercules but without the appetite of Gargantua!

In the Dubna, Brookhaven, Serpukhov, and similar accelerators, the flux of particles is aimed at an immovable target. On striking it the proton-bullets force its nucleus to rebound elastically like a punching bag when a boxer's glove hits it. The effect of the collision is much less than if it met a 'microglove' moving toward it. And the more powerful ordinary accelerators are, the smaller is the proportion of the energy of their beams that is put to use.

A way out of this impasse has been found in the technique of head-on collisions of beams. Four years ago it was tested successfully in Novosibirsk in experiments on apparatus with opposing streams of



particles (electrons and positrons). A year later an analogous accelerator was working in France, and later still another in Italy.

With the new accelerator in Akademgorod it is planned to use the collision of protons and antiprotons. The energy of the particles in each beam will be 25 GeV. The sum might seem to be 50 GeV, but the much greater efficiency of the collisions leads to results that it would take an ordinary 1300 GeV accelerator to obtain. The cost of a 1300 GeV machine (with a stationary target), by world standards, would be more than a thousand million dollars. The Novosibirsk installation is far, far cheaper.

'I don't want at all to imply that the time of the accelerator with stationary targets is already past,' Prof. Budker concluded his *Pravda* article, 'but there is no doubt that the future of very high energy physics is with head-on beams.'

Similar problems face other branches of science. Because the ideas industry, like the production of things, is unimaginable without powerful (and alas, costly) equipment; and in many fields it competes in tempos of modernization with industry.

Indeed, even theoreticians (like mathematicians, for instance) cannot make do with their traditional tools, pen and paper. By no means. They very often have to resort to the services of powerful apparatus like electronic computers. What is to be said then about experimental scientists? Ours is no longer an age when great discoveries are made with home-made equipment, as in the days when a scientist

mocked something up with his own hands from bits of iron and pieces of wood held together with string and sealing wax. Accelerators and reactors, quantum generators, and superfast centrifuges, huge radio telescopes and electron microscopes, geophysical rockets and interplanetary stations, *lunokhod* laboratories, and robot-drillers are the arsenal of science today. And its instrumentation must grow at least 50 per cent faster than the number of researchers—that is the lead accepted as advisable by none other than the scientists of science. For the 'stock of machine tools' in the ideas factory becomes obsolescent in four or five years and requires constant renewal.

That being the case the problems of meeting the demands of science and the possibilities of satisfying them are becoming more and more urgent. But won't the mutual interests of scientists and state, as exist in our society in the USSR, really help to solve it?

The socialist state generously finances science, which is the 'most powerful form of wealth' for it, as Marx put it. In 1971 the USSR spent 13 000 million roubles on its development, which was twice as much as was budgetted in 1966, and almost ten times as much as in 1956, a growth rate that is one of the fastest in the world. And it is the duty of scientists to do everything they can so that not a single rouble spent is wasted, and so that it will be returned to society a hundredfold.

The Directives of the 24th Congress of the Communist Party of the Soviet Union for the ninth five-year plan envisaged further consolidation of the experimental and pilot-plant bases of research—and along with that a decisive improvement in the efficiency of scientific institutions.

That is quite natural. In presenting Soviet science with new opportunities, socialist society also pre-

sents it with new demands: 'to accelerate the pace of scientific and technical progress by way of all-round development of research in the most promising fields of science and reduction of the time taken to introduce the results of research into industry, and to implement the replacement of manual labour by machines on a broad scale,' it says in the directives.

Those are tasks in the solving of which science and scientists have a front-rank position. But the directives also spoke of the responsibility and obligations toward science and scientists that society must take on in order to facilitate these new tasks and ensure their fulfilment.

'Consistently to raise the standard of education and the qualifications of working people, to complete the transition to universal secondary education for the youth, and to take the necessary steps to train highly skilled specialists and workers and retrain personnel in connection with the introduction of new technologies and the improvement of production organization. . .'

The Directives said further that the ninth five-year plan would be new, convincing confirmation of the superiority of socialism.

'Our country is on the upsurge, and is all the time consolidating its economy, developing science, technology, and culture, and raising its international prestige and authority,' M.V. Keldysh, President of the USSR Academy of Sciences, said at the 24th Congress. 'The complex problems still arising before us are the difficulties of growth, which are linked with the rapid growth rates of our economy. . . . Scientists dispose of all the forces for the further development of science, and to accelerate technical progress for the good of the people, in the name of the great cause of communism.'

Yes, in a society free of class antagonisms there are no unresolvable contradictions. The co-incidence of the interests of the working class, peasantry, and intelligentsia (which includes the great detachment of scientists) is a guarantee that all the tasks dictated by life and formulated in our national plans by the Communist Party and the Government will be carried out. These are the best conditions for resolving every problem that is being raised, or will be raised, by scientific and technical progress.

Banishing the Demogorgon

America in darkness!? The Great Blackout! The Breakdown of the Age! Readers avidly read the sensational reports, but that was already afterward. *Then*, when it happened, it was clearly beyond a joke; in the state of atomic hysteria it seemed that nuclear war could have begun. Sheer panic developed.

Can you imagine New York without the Great White Way? On that autumn evening Broadway's great garish spectacle of electric signs was blacked out. But it was much more than that. Myriads of electric suns went out at once over a territory with a population of thirty million. Eight hundred hospitals were without light, not to mention cinemas, railway stations, post offices, and houses. Gas and water were cut off, for the electric hearts of the pumping stations simultaneously frozen into immobility and literally suffered mass infarct. Lifts stuck between the floors of skyscrapers. More than 600 000 passengers found themselves trapped in crowded cars between stations on the New York Subway—by the irony of fate transport was suddenly paralysed at

the rush hour. And to crown it all, communications were cut.

Worldy-wise, sophisticated America had never known such a strike. A strike of machines! And it did not last for just a few minutes but for hours. The pitch darkness that fell on eight north-eastern states of the USA and two Canadian provinces on 9 November 1965 was only finally dispelled when day broke the next morning.

It all began as a mere trifle. At 17 hours 16 minutes 11 seconds local time one of the high-voltage transmission lines of CANUSE (the 48 000 megawatt U.S.-Canadian power grid) went out of action. It was nothing special, a flash-up of power like a short circuit in a house. And, as happens in such cases, a 'fuse' blew.

The whole miles-long power line was automatically cut out. But the power carried by it only disappeared for the consumers; the power stations continued to generate it as before. Being interlocked they spilled it over into neighbouring channels. But these channels, however (it being evening!), were already at peak load. So their safety defences, of course, also went into action. The grid was reduced but the Niagara of electricity pouring into it did not slacken!

Catastrophe was only minutes away. It was time for the dispatchers to gather their wits. From the moment the automatic cut-out first operated one minute passed, then a second, and a third began. But for some reason people delayed. The fiery wave grew apace and broke like a hurricane against the still open channels of the system. The system became choked and the whole concrete Leviathan of the East Coast of America—the dense industrial complex as far west as the Great Lakes—fell into a deep swoon.

America in the shadows! But not because its elec-

trical streams had run dry. On the contrary, they had overflowed their banks. H.G. Wells, the author of *Russia in the Shadows*, would probably never have imagined such a paradox; but what is the use of remembering his textbook example of shortsightedness here? Many American commentators, speculating on the cause of the catastrophe, could have outdone Wells without difficulty in the line of fantasy. Some of them hit upon propositions that would have done honour to the author of *The War of the Worlds*—'sabotage', they said, by invaders from other planets. And the simple-minded believed them, so much had been written in recent years about 'unidentified flying objects'.

The myth of the Demogorgon was also exhumed from its funeral barrow of books. A conspiracy by the Robots' Union! Which was just to be expected. Having created Mechanisms and Machines, we ourselves had linked them up in Systems, and the Systems into a System of Systems. A kind of state within the state had developed, immense but inconspicuous. The all-pervasive CANUSE system looked quite harmless from the outside but just the same it was some sort of underground organization embroiling thirty million people in its toils. But hadn't we wanted to see its 'electronic group' as clever as possible? But it was crafty! What had been naively taken for meek and submissive slaves were potential rebels and mutineers.

In spite of all their speculative character these revelations convinced many people more than conjectures about 'flying saucers' since they were corroborated by respectable scientists.

The idea wasn't new. Back in the Twenties, Wells' countryman Prof. Haldane had drawn attention to the fact that the opponents of science were already



asking whether mankind had not 'released from the womb of matter a Demogorgon which is ready to turn against him and at any moment hurl him into the bottomless void'. And before that the 'thinking machinery' to come had been pictured as a demonic, venomous creation that would visit untold calamities upon its creator. That was in the old days. But now?

Now, soon after the Great Blackout, a book came out in 1967 *The Search for Robots* by A. Cote, an expert on cybernetics, with a whole chapter on the Breakdown of the Age and descriptions of artificial superorganisms that would always react to danger faster than man but not always in the interests of man. It had a significant resumé: Beware of the Invisible Robots!

You may only smile at these attempts to frighten us with ghosts. 'Robotphobia' is only considered natural in an atmosphere of the technical fetishism ridiculed long ago by Karl Marx but still surviving in the West. There, today, it is the idolatry of the cybernetic age, but as before the products of scienti-

lic and technical thought were assimilated with the results of religious fantasy.

The causes of the Great Blackout proved not to be so mysterious. Here is what a journalist of my acquaintance was told when he consulted authoritative specialists at the USSR Ministry of Power and Electrification.

'The demonic force allegedly possessed by a large artificial system had nothing to do with it. CANUSE is a conglomerate of private capitalist domains where no one gives orders to the lord of the manor. The owners, when harnessing the horsepower of their generators into a common power system, were guided, of course, by considerations of mutual advantage and *profit*, but almost never by considerations of *mutual aid*. At the critical moment no company wanted to cut *its* plants off from *its* customers; otherwise they would have to pay a penalty. So they all went down together, and because of that tens of millions suffered.'

Accidental difficulties are never excluded, but they cannot, and should not, be allowed to pile up into a catastrophe. The first to counterattack the chaos, of course, were the electronic load dispatchers; they react quicker than people in any emergency. But people programme the automatic systems! And link them up into a system. It would seem clear that everything should be so arranged that the system immediately isolates the danger centre while it is still small. There is no great harm if a few people—an insignificant minority—are temporarily the losers. And then again a local disruption of service can be remedied quicker than when it has spread everywhere. But systems differ, apparently.

We must admit that sensible Americans have long understood what is what. The Federal Commission that investigated this scandalous incident drew the

firm conclusion, with no tinge of mysticism, that today's complex electricity industry needs co-ordinated regulation on a national, and even an international, scale. The USA, it recommended, should have a single power system with a national, state controlled dispatcher centre.

To gain experience of protection systems American experts came to the USSR. They consulted us, of course, in the hope of getting some technical improvements. For they had to do something. But alas, after the Accident of the Age the American power companies were back at square one more than once, though not so catastrophically. But where is the guarantee that the Great Blackout will not be repeated?

A few days before the results of the Soviet state plan for the first half of 1972 were published in Moscow, the press reported some other news from New York worth noting. On 18-19 July 1972, as it happened, nearly half a million New Yorkers were without electricity because of a breakdown on the transmission lines. It is possible that some writers will again call in the traditional Demogorgon to explain it. Our advice is simple: Go meet it, and drive it out!

'All for one, and one for all', or 'each for the aid of the others', is quite another principle and gives quite different results. In fact, it's another world.

The winter of 1970 was unexpectedly cold and snowy in Europe. Coal-getting in the open-cast pits of Poland and Czechoslovakia encountered unprecedented difficulties—cold, blizzards, and snowdrifts. Power stations were put on tight fuel rations but current was wanted and needed according to plan.

The USSR and other socialist countries, members of the Council for Mutual Economic Assistance, CMEA (or Comecon as the Western Press calls it),

immediately came to the rescue of their neighbours, and made deliveries of power above plan. The additional current was passed along the lines of the 'Peace' United Power Systems. Where did such sizeable reserves come from? Are unbalanced surpluses possible here?

First, a word about the size of the 'Peace' System. Its capacity is approximately 60 000 megawatts. It covers a territory with a population of 100 million people in Bulgaria, Czechoslovakia, the German Democratic Republic, Hungary, Poland, Romania, and the western parts of the USSR.

'The parallel working of our power systems greatly improves the reliability of power supply in each of these countries,' says K.S. Storozhuk, the member of the collegium of the USSR Ministry of Power who represents our country on the council of the Central Load Dispatcher Board of the 'Peace' System in Prague. 'We can always come to each other's aid.'

Mutual aid—that is the alpha and omega, the letter and the spirit of the integration and unification of forces under the aegis of the Council for Mutual Economic Assistance, and in particular of the integration of their power systems into a system of systems. That is the end of the whole scientific and technical arsenal of the 'Peace' System, which continues to be automatized, and more vigorously now than ever before.

There are no two ways about it; here is an automatic system, and however it is programmed, it is still only an automatic system with far from limitless possibilities. But no one overestimates them. Machine reasoning is supplemented by human intellect and—forgive my metaphorical licence!—by human hearts, without which the brain is an orphan. With such a combination the shortcomings of the one are compen-

sated by the advantages of the other. There is no 'machinomania' here; nor its opposite, 'machinophobia'.

The 'brain centre' of the United Power Systems, which is located in Prague, has been working now for more than ten years, co-ordinating their joint operation through the national load dispatcher boards of the seven socialist countries. These years of experience of continuous power supply have demonstrated the functionability of the whole complex of scientific, technical, social, and economic premises on which the Systems rest.

The dialectics of integration at times simply amaze one.

Can the sum be bigger than all the separate items making it up taken together? At first glance it seems a strange question, in crying contradiction with the most elementary rules of arithmetic. That is just it—arithmetic!

Some crank of a scientist once compiled a 'recipe for man'. 'What is *Homo sapiens*? This "pinnacle of creation", lauded in every key?' he asked. 'For the analytical chemist he is nothing more than a container of water and a handful or so of "dry residue", with such-and-such components worth so many dollars and so many cents. Not rich, as they say.'

But it is quite possible that the author of that curious calculation wanted to illustrate the pointlessness of a primitive approach to a complex organism, to a *big system.* However modest the dimensions of a living creature, does it really amount to nothing more than its elements? It doesn't even amount to its more complex constituents, or to its various systems (nervous, cardiovascular, etc.). We owe such a marvellous thing as human reason to their very complex unification and not to their simple mechani-

cal summation, to the complex and not to the conglomerate or aggregate.

It is the same with the 'Peace' System. It is the result of integration which produces something organically whole, and in sum is much more than an aggregate of its individual power systems.

This wise, wise, wise, and good world is an example of the dialectical transition of quantity into quality.

The peak hours for the power systems in the different countries do not coincide. That, it might seem, spells nothing but trouble; loads must be redistributed; the automatic controls must be improved and superintended. But the possibility of manoeuvring the fluxes of electricity and regulating the working of generating stations and transmission lines more flexibly makes it possible to liberate additional capacity—and not just a piddling amount, but up to 1,500 megawatts.

In socialist conditions this integration opens up new prospects for the economies of the countries as a whole. Each member of the community now has the possibility of organizing its power system, the basis of its whole economy, more rationally. The gain is obviously not simply in reliability, and it more than covers all the expenditure on building, operating, and improving this huge grid (which continues to grow).

The capacity of the 'Peace' Power System is expanding all the time. In 1970 its customers received 260 000 million kilowatt-hours of electricity, and in 1971 280 000 million kilowatt-hours. A sizeable proportion was supplied, as before, by the USSR, the biggest power producer in Europe, which is increasing its generation of electricity at high tempos (just compare these two figures: that reached not long ago,

in 1970—740 000 million kilowatt-hours; and that to be reached soon, in 1975—1030-1070 000 million kilowatt-hours).

The other members of CMEA are also increasing their installed capacity. That means that an even more powerful stream will soon flow along the transmission lines of the 'Peace' System.

Is there any danger, however, that this stream will overflow its banks? None at all. There is no place for such a transformation of quantity into quality in socialist conditions of integration. The threat of an electrical flood, and ways of preventing it, will still be a pressing problem tomorrow, of course, but the Soviet Union's partners in CMEA have access to its long experience of electrification, and of building an even bigger unified power system, the largest in the world.

There are now approximately a hundred regional or district power grids in the USSR. When linked together they will form eleven bigger systems or units like the Transcaucasian, Central Asian, Siberian, and Far Eastern systems. Seven of these eleven are linked together in the Unified Power System of the European Part of the USSR. Along the metal veins of these seven grids a truly fiery river circulates coming from 600 generating stations with a total capacity of 110 000 megawatts. Co-ordination of all the subsystems by the Joint Board is done from a central control point in Moscow. The grid operates without a hitch.

The Unified Power System of the USSR will be even more vast, and will serve all fifteen republics of the Union. It is expected to finish building it in the 1980s. It is difficult to exaggerate its significance for a country covering one-sixth of the land surface of the world (and eleven time zones). Rational distri-

bution of loads in accordance with continuously changing demand, and the switching of surplus capacity to areas where there is no surplus at a given moment is quite feasible when the possibility exists of conducting this mighty 'symphony' from a single control point.

The convenience, benefit, and reliability of the systems will be more appreciable still when the unified power system for the whole of the USSR begins to function. But in order to link up all the power stations of the country it is necessary to build new high-tension lines thousands of miles long, and to plan them at high load-carrying capacities, in other words at higher voltages (no longer 500 kilovolts as now, but 750 or even 1150 kilovolts for alternating current and 1500 kilovolts for direct current). The problems involved are not easy in either the engineering or the simple accounting sense. Neither the working out of plans nor their practical realization is possible without massive capital investment.

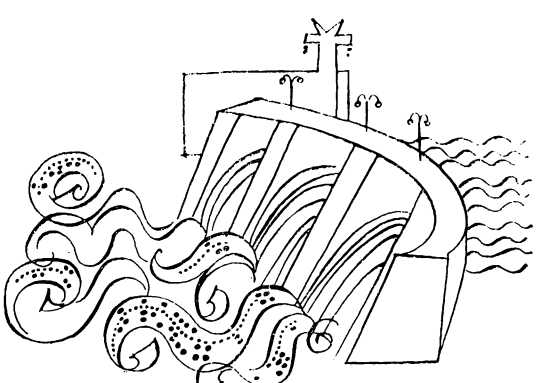
A socialist state does not, understandably, stint on such expenditure, for it is a matter of the consumers and of meeting their needs; but for all that it is quite natural to strive for a solution that will give the desired end at the lowest cost and not any old solution, even if it will pay for itself a hundred times over.

Maximum quality with the minimum quantity is what is needed for the transition from quantity to quality that accompanies the integration and unification of systems into a system of systems. And here, in realizing this reasonable point, the systems approach helps a great deal, an approach that has been developed by a special discipline called into being by the scientific and technical revolution.

The synthesis of a complex like a unified power

system for the USSR must clearly be preceded by analysis, to check the harmony by algebra, but never in the manner of Pushkin's Salieri: 'Having killed the sounds, I decomposed the music like a corpse.' In fact, if we are interested in the behaviour of a big system as a whole, it is absurd just to study its organs all nicely preserved in alcohol, one by one, separately. What is needed is something like a physiological investigation with the appropriate methods and appropriate instruments.

The science of big systems is still young but it already has its own research apparatus. Its techniques, unlike those of other sciences, do not assume far-reaching simplifications, when it is quite impossible to judge the result of complex synthesis from the results of analysis, however conscientious and scrupulous (remember the 'recipe for man'?). There are no two ways about it; that way one resorts to dismembering the whole (figuratively speaking, of course), but it won't do if vitally important connections between the subsystems are cut.



The development of the theory of big systems marks the transition from the 'anatomical' to the 'physiological' era in their study and is a new, really revolutionary stage in the practice of building them.

The systems approach is not simply fruitful in application to power complexes. The economy as a whole can be looked upon as a Big System consisting of numerous subsystems, and in particular of networks like the power and gas grids, and so on. Can you imagine what it means to 'check the harmony' of the economy as a whole by algebra? It means putting production and distribution on a strictly scientific basis so that everything will be for the best and the maximum effect will be achieved in every case by the minimum of means.

And if the building of a unified power system on a scientific basis brings vast benefits, what should we expect from a qualitative new leap! At least the sum of the benefits of all the rationally organized subsystems.

But is the problem fully solvable? For the Soviet economy is immense in size and is getting bigger all the time. Its countless branches are also proliferating and the connections between them are immeasurably more complicated than they once were. And what will they be like in a few more years, or decades!

The task is certainly supercomplicated. But—and this is extremely important—its solution is not only not hampered by social conditions in the Soviet Union, but is positively assisted by them. It is quite another thing where the competition of private ownership converts power complexes like CANUSE (and similar systems) into 'patchwork quilts' sewn together with the white threads of commercial interests. Market forces, which exclude national planning,

reduce the recommendations of the systems approach to naught, although American and other Western scientists are now working intensively on it, and not without success.

Reason against anarchy, the eternal contradiction between the forces of order and chaos, finds clear expression in the realm of big systems. The guarantee of the victory of reason over the elements is a correct, unified strategy.

An artificial superorganism is not simply a system of systems, it is a controlled system consisting of controlled subsystems, autonomous but united by a common aim and closely linked in structure and function. The integral (and most important) element of control that is indispensible at all levels of its hierarchy of subsystems, moreover, is nothing more nor less than planning, combined with forecasting. And both must be at once operative and long-range. Why? And what for?

A specific feature of big systems is their dynamic character. When you look at a high-tension transmission line, at the lifeless skeletons of its pylons standing rigid on the ground, and at the slack cables crisscrossing the sky in parallel lines, it is rather difficult to imagine their world of tense dramatic collisions. Yet the gangling steel giants that seem to have fallen asleep forever with outstretched arms and garlands of insulators hanging from them are participants in a superfast fiery relay; each transmission line lives its own seething troubled life.

The 'fossil' character of the system is as illusory as the immobility of a tongue of flame or the funnel of a whirlpool. Before us is a dynamic, mobile equilibrium in which all fluxes—incoming and outgoing—must be balanced every moment, consciously, always, and everywhere!

'*Panta rei*!' said Heraclitus of Ephesus. 'All is flux!' And as if repeating the old Greek philosopher, Norbert Wiener, the 'father' of cybernetics, who called his brainchild the science of control and communication in animals and machines, compared the living organism with an eddy. A creature is metabolism, exchange of matter, unceasing and ordered. It is beautifully balanced power engineering. It is perfectly adjusted regulation, responding every second to signals from within and without. And an economic organism? Along its nerves and arteries, and through its cells, also circulates a stream of materials, energy, and information. And they must also be regulated at every moment, always, and everywhere. Otherwise there is paralysis, as with the Breakdown of the Age.

But that is not all. Unlike its biological analogue, an artificial superorganism is practically immortal. It never stops developing. But, for its development always to be proportional and harmonious, it must obviously be planned. You may object that surely programmes of development are also drawn up in capitalist countries for many years ahead. In France, for example, they have five-year plans (the sixth already!) and there is a special commissariat for planning. But here is what an observer has to say.

'Once I asked the head of a French firm: "Do you communicate your plans to the Commissariat?,"' N.P. Lebedinsky, member of the collegium of USSR Gosplan, relates. '"Not a bit of it, Monsieur Lebedinsky. How could we? If the Commissariat knew tomorrow, our competitors would know the day after". . .' Just try and imagine what it would be like if the plans of our Soviet factories and industries were kept secret from the others. It is quite unimaginable, the negation of the very basis of planning.

The simple adding up of the internal plans of firms opposed to each other can really only generate a conglomerate like CANUSE but not a complex. The maximum effect is only obtained when planning is unified and national, such as first became a reality in the USSR.

Back in 1920 the first national plan-forecast in history was drawn up, worked out by the GOELRO Commission. Here is how the novelist Alexei Tolstoy described, with historical authenticity, the days in December 1920 when the Seventh All-Russian Congress of Soviets discussed the GOELRO Plan. Disorganization, hunger, cold, disease, and civil war were rife within the country; outside blew the winds of 'cold war', political boycott, and economic blockade.

'. . . The great auditorium of the Bolshoi Theatre with its five tiers of boxes was scarcely lit by the hundreds of incandescent bulbs in the fog exhaled by the people. It was as cold as a cellar. . . . Everyone, craning their necks, was staring at the back of the stage where a map of European Russia covered with circles of various colours hung down from the flies. In front of the map stood a little man in a fur coat. Raising a pointer he indicated future power stations, and the circles lit up, bright as stars in the gloom of the vast stage.

'In order to illuminate the map for a brief instant, it had been necessary to concentrate the power of all Moscow's power stations, and even in the Kremlin, in the offices of the People's Commissars, all light bulbs had been extinguished except one of sixteen candlepower.

'The people in the auditorium, in the pockets of whose army greatcoats and shabby overcoats was the handful of oats that had been issued that day in-

stead of the bread ration, heard about the intoxicating perspectives of the Revolution.'

The GOELRO Plan envisaged the building of thirty district power stations over ten to fifteen years. What is not so well known is that in addition it also surveyed a longer prospect and proposed the building of a hundred district power stations. It also considered a number of projects, namely the building of a cascade of hydro-electric stations on the Volga and Angara, the digging of a Volga-Don Canal, the development of the Great Northern Sea Route, the building of main-line railways to link up with foreign railways, and the establishment of broad international co-operation.

Even the (by present standards) modest programme of electrification for ten or fifteen years seemed fantastic then. H.G. Wells called Lenin 'the dreamer in the Kremlin'. But what had seemed technically unrealizable proved feasible in the new social and economic conditions born of October 1917, and was long ago accomplished. In 1922 the Union of Soviet Socialist Republics was formed; and did it not become a whole incomparably greater than the aggregate of the fifteen of its parts taken separately? United in that Union the peoples of all the Republics increased their opportunities tenfold as it were.

But here is an interesting point. The systems approach is considered a revelation of the scientific and technical revolution that developed in the middle of our century. But already, fifty years ago, in 1922, favourable bases for it began to be laid, and they were scientific as well as social.

The GOELRO Plan was a complex one. It blazed the way not only for electrification but also for power engineering as a whole, the iron and steel industry, mechanical engineering, and transport. Lenin

insisted that all the plans of the separate industries must be strictly co-ordinated and put together in a single, agreed programme.

Those were the principles that subsequently underlay the Soviet five-year plans. Now the experience of the USSR is being taken up by other countries.

In 1971 the member states of the Council for Mutual Economic Assistance adopted a Complex Programme of Socialist Economic Integration, which, it is envisaged, will be carried out in stages over the next fifteen or twenty years. It is a single, agreed, international programme.

Present-day planning, both national and even more international, is incredibly complicated, of course. It calls for a much more precise approach than the first Soviet five-year plans. Exact and objective calculation of diverse variants is needed in order to choose not simply the best of those acceptable but the optimum one, the one most advantageous, the best one in the given circumstances.

But such are the dialectics of development that the scientific and technical revolution, which is raising new problems for planning, is also helping to solve them. For it is a matter, in general, of automating planning and management, employing fast electronic machines and precise mathematical techniques.

Are systems always needed? The Directives of the 24th Congress of the Communist Party of the Soviet Union for the ninth five-year plan envisage continuing the building of a whole number of national systems. But what systems? We have already mentioned the United Power System for the USSR. There is also to be one for gas, a single gas grid that will be laid and developed in the same planned way.

In the eighth five-year plan the total length of our gas lines rose from 42 000 to 70 000 kilometres, and

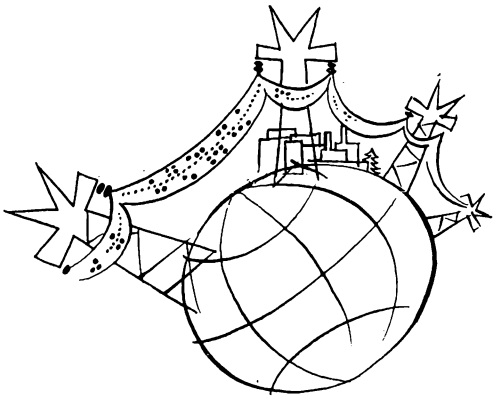
should reach 100 000 in 1975. Soon whole Volgas of gas will flow along these steel channels. In 1975 the USSR will be producing between 300 000 and 320 000 million cubic metres of natural gas, half as much again as in 1970; and the limits of further growth are not yet in sight, for the Soviet Union possesses the richest reserves in the world of this valuable raw material and fuel.

New trunk pipelines will make it possible to increase exports of natural gas to Czechoslovakia and Poland, and to begin to supply it to Bulgaria, the German Democratic Republic, and Hungary. An interstate unified gas grid like the 'Peace' Power Systems is being laid. And the pipelines will stretch even further west to Austria, West Germany, France, and Italy.

What about oil pipelines? Their network is also taking on a transcontinental aspect. One system, the 'Friendship' pipeline, begins near Kuibyshev on the Volga and goes to Halle in the German Democratic Republic. It is all of 5000 kilometres long; and with the branch that goes to Irkutsk will be 10 000 kilometres long. A second 'Friendship' pipeline is being laid parallel to the first. By the end of the ninth five-year plan up to 50 million tons of oil a year will be being pumped along this arterial system, the biggest in the world.

System? Yes, a vast, steadily developing system of arteries. But it and all the other pipelines of the USSR are not yet linked up in a system of systems like the unified gas grid. The reason is that oil is not used in the crude form; after being extracted it has first to be passed to refineries; and their consumption is more or less stable and can be planned with some confidence.

Gas calls for special tactics. Like electricity it is



a ready product that can immediately be sent direct to consumers. Demand is not controlled and is subject to daily and seasonal fluctuations that are hard to predict. Firm planning is impossible. Operative information is needed from all consumer points, and is collected together in Moscow at the central control point. From it the ebb and flow of gas is smoothed out by remote control.

Flow can be diverted and redirected because of the linked character of the trunk lines that is a special feature of the grid (and, incidentally, of the power grid, too).

The system works without interruption. Much still remains to be done, naturally, to turn it into a faultless united gas grid for the whole USSR, but the difficulties are purely technical and scientific. They are not complicated by social problems (in the USA, for example, there is also a developed network of gas pipelines, but it is not really simple to link them up, for the owners are apt to squabble among themselves).

But to revert to oil, how do things go there? We have no need, of course, of a system like the unified gas grid, but that doesn't mean that there is no need for a systems approach.

The most advantageous variant is also needed here so that the network of pipelines linking oil fields and refineries is built as economically as the cardiovascular system of an organism, in which there is nothing surplus and everything is for the best. The precision of mathematical and economic techniques processed on fast computers is a help in resolving these problems. That is the way the optimal national plan for the location and development of oil fields and refineries was worked out for the USSR.

In order to analyse all the variants and select the one most suitable a system of 450 equations and 2900 variables had to be solved. The number of starting figures alone was 19 000! If all the calculations had been done 'by hand' on comptometers the plan would probably have been stillborn because they would have taken many years more than the period for which it was being drawn up.

The Soviet BESM-6 fast computer, which has a speed of a million operations a second, coped with the job in good time. The saving in capital investment alone was 800 million roubles.

Similar exercises have been performed for the chemical and motor vehicle industries, and are being mounted for other branches of the Soviet economy. But our scientists consider something feasible, and incomparably better, that would have seemed quite fantastic not long ago. This is SOPHIE (or rather SOFE), meaning System of Optimal Functioning of the Economy—yes of the economy as a whole (not just its separate subsystems), a whole Big System embracing the whole Soviet economy.

To develop a unified national, automated system of collecting and processing information for accounting, planning, and managing the economy on the scale of the USSR as a whole, that is the fascinating and very real job put to our experts by the Directives of the 24th Congress of the Communist Party. It is the real System of Systems. The technical basis for it is the national networks already being developed: (a) the state network of computer centres now taking shape; and (b) the state system of communication lines and centres.

It is a tremendous task requiring more than one five-year period; but the effect will be stupendous. Everyone will gain from it, all the people of our country, the Soviet state as a whole, and the entire world camp of socialism.

Epilogue?

An epilogue? No, to be continued! You will find the continuation, which is much vaster than these sketchy notes, which cover only its most general outlines, in the literature on big systems. The continuation will not only be interesting and stimulating but will also be important, for you yourselves, and for all who are engaged in building communism. It is a great, new cause, opening up vast prospects of activity for young people.

The library of popular descriptions of this theme is still quite modest, of course. And there is nothing remarkable in the fact that books by foreign writers have their place in it. But, while giving them full credit for all their real scientific achievements, we must be on the alert when some of them begin to philosophize in the spirit of technical fetishism. Today, in the age of the technical and scientific revolution, what Lenin said in 1908 in *Materialism and Empiriocriticism* is very applicable. '*Not a single one* of these professors, who are capable of making very valuable contributions in the special fields of che-

mistry, history, or physics, *can be trusted one iota* when it comes to philosophy. Why? For the same reason that *not a single* professor of political economy, who may be capable of very valuable contributions in the field of factual and specialized investigations, can be trusted *one iota* when it comes to the general theory of political economy. For in modern society the latter is as much a *partisan* science as is *epistemology*. Taken as a whole, the professors of economics are nothing but learned salesmen of the capitalist class, while the professors of philosophy are learned salesmen of the theologians.'

'From its very birth the Soviet state has demonstrated the possibility and the need to forecast the development of economics, science, and technology,' D.M. Gvishiani, Corresponding Member of the USSR Academy of Sciences, and V.A. Lisichkin write in their book *Forecasting*. 'An example of forecasting with the stamp of genius is Lenin's *Draft Plan for Scientific and Technical Work*. It can be said without exaggeration that the history of modern scientific-technical and economic forecasting began with that document. And an immense role was played by the GOELRO Plan worked out in 1920-1 on Lenin's initiative, the first directive plan and forecast in history of scientific and technical progress for several decades ahead.'

Those years 1920-1 were the time when J.B.S. Haldane and Bertrand Russell were still only touching on the problems developed by them in their booklets *Daedalus* and *Icarus*; and when H.G. Wells was still only thinking in his study, between trips on the 'time machine' to the rosy land of Utopia, whether or not to take a peep at that uncomfortable Russia, disorganized by 'discord'; when Lenin and his expert advisers were already drawing up a pro-

gramme of great works to turn a crippled and feeble country, ravaged by war and suffering from cold and hunger, into a rich and powerful state.

During the preparation of the GOELRO Plan Lenin already had the idea (which had hardly yet entered the heads of European or American scientists, let alone politicians) of developing a rational forecast of the development of the productive forces for thirty or forty years ahead.

The term 'futurology' was not yet in currency, but it was then that the first steps were taken in the direction that subsequently led to the development of a special discipline of forecasting.

In the Twenties Soviet scientists were not a bit behind foreign ones in forecasting; if anything they were ahead of them in many respects. And in recent years dozens of research groups concerned with problems of scientific-technical and social-economic forecasting have been set up. Much attention is being given to it by the Academy of Sciences, the State Planning Commission, the State Committee for Science and Technology, and other bodies.

Soviet forecasters, basing themselves on Marxist-Leninist methodology, and employing the most modern scientific and technical equipment, see the future of scientific and technical progress as inseparable from social and economic progress.

'The most important features of the present stage of our economic development,' L.I. Brezhnev said in his report to the 24th Congress of the CPSU, 'are also being determined by the rapidly developing scientific and technical revolution. Socialism and the planned socialist economy are opening up the broadest prospects for the all-round progress of science and technology. At the same time the scientific and technical revolution is demanding the improve

ment of many aspects of our economic life. In other words, here is a huge force, favourable to socialism, but requiring to be harnessed now. . . .

'We are faced, comrades, with a task of historical significance, *to link the achievements of the scientific and technical revolution organically with the advantages of the socialist system of production.*'

The fact that the twentieth century has been a century of stupendous growth of the productive forces and development of science, and yet hundreds of millions of people have still not been freed from poverty, and an abundance of material and spiritual wealth has not yet been created for all the people on earth, is the fault of capitalism, and of capitalism alone, says the Programme of the Communist Party of the Soviet Union.

The essence of our times is the transition from capitalism to communism. And that is the grounds and the basis of our optimism.

TO THE READER

MIR PUBLISHERS would be grateful for your comments on the contents, translation and design of this book. We would also be pleased to receive any suggestions you may wish to make.

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There is a story that early in the last century the Emperor of All the Russias ordered the word 'progress' to be suppressed. Today, in our day and age, with its stormy, rapid development of science and technology, there are many philosophers, economists, and historians who would like to do the same. Prof. Max Born,F.R.S., said in his *Physics and Politics* that things today differed more from his childhood than those halcyon days did from the time of Julius Caesar 2000 years before. For his coevals in the Soviet Union the changes have been even greater. They have lived through three revolutions, torn the old system apart, built a new one, and have seen the rise of a world socialist system. Is that not progress?!

But in skirmishing with the pessimists who deny progress it is necessary to know what progress is. What, for example, is scientific and technical progress? And what are its links with social and economic progress? In this book Leo Bobrov, scientist cum publicist, discusses these questions and argues that we have full grounds for optimism not only when contemplating the future but also in building it.

After graduating in chemistry from Moscow University in 1959, Leo Bobrov did research for several years in the Institute of Physical Chemistry of the USSR Academy of Sciences. There he developed a taste for popularizing science which led him into journalism with the Novosti News Agency. In addition to *Grounds for Optimism*, Mr. Bobrov has published several books on the methods and ideas of modern chemistry and physics, and is currently working on one about statistics.